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Measuring The Impacts Of Environment Canada's R&D: A Case Study of Pulp & Paper Effluent Research

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MEASURING THE IMPACTS OF ENVIRONMENT CANADA'S R&D

CASE STUDY: PULP & PAPER EFFLUENT RESEARCH

– FINAL REPORT --

Submitted to:

Environment Canada

Submitted by:

Marbek Resource Consultants

In Association with:

SECOR Inc.

September, 1997

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EXECUTIVE SUMMARY

Background and Objectives

Environment Canada retained the services of Marbek Resource Consultants and Secor Inc. to help identify, describe and measure the impacts of Environment Canada (EC)'s Research and Development (R&D).

The project is one of eight projects included in the *Business Plan for Managing R&D at Environment Canada, 1996-1997* and responds, in part, to the 1994 *Auditor General's Report* and the 1996 *Federal Strategy for Science and Technology*, which suggested a need for increased accountability for R&D results. The project is directed by a Steering Committee composed of members of each of the Department's Services (see Appendix A).

The objectives of the project are to provide a rigorous documented evaluation of the impacts of two programs and to validate an approach to the evaluation of such impacts. The two chosen programs are: pulp and paper effluent R&D and stratospheric ozone depletion R&D.

In choosing two different projects, the Steering Committee sought to examine research activities with different characteristics. In the case of ozone, the research contributed to an international effort leading to global action, whereas in the case of pulp and paper, research was focussed on the content of imminent regulations. The case studies also represent efforts of two different research groups within the department and different aspects of the environment. The expectation of the Committee was that, as a result of its direct link to regulatory policy, pulp and paper research was more likely to have had significant quantifiable economic impacts. By selecting case studies with these different characteristics, it was hoped to learn more about the feasibility and approaches to measuring the impact of R&D.

Approach

The heart of the approach taken by the Project Team was the development of an "Impact Map" which is a graphical representation of the linkages between the outputs of the R&D and the various policy and behavioural changes leading to ultimate impacts and socio-economic implications. The aim was to provide an explicit and transparent description of the chains (or threads) by which the impacts of the R&D are realized. In the process of developing the Impact Map, certain impact threads were identified as priorities for analysis, because of the likelihood of significant impact or the likelihood that those impacts could be credibly identified.

The significant impact threads were explored through interviews of key individuals who were involved in the application of the R&D results and through the review of reference documents.

The analysis focused on developing the following:

- A reasonably accurate description of what actually happened (in terms of regulations and costs)

- A best estimate of the relative contributions of the different researchers to the R&D results (based on an overall assessment of the interview results), together with reasonable high impact and low impact scenarios for NWRI's contribution
- A series of credible scenarios of what might have happened in the absence of the knowledge, together with estimates of the probability of each scenario (where possible)
- A qualitative assessment of what might happen in the future as a result of emerging impacts.

Using these estimates, the Project Team was able to describe and in some cases quantify the socio-economic impacts of the R&D under various scenarios. Although there is significant uncertainty associated with the results, it is believed that, at a minimum, they provide a good indication of the value for money of the R&D and can be used, albeit with caution, in science policy and planning.

Description of the Pulp & Paper Effluent Research Program

The original goal of the R&D was:

- *To advise the Department on options to eliminate, reduce or mitigate adverse impacts from pulp and paper effluent.*

As the Department's policies were being developed, and regulations were being developed, two additional goals emerged:

- *To determine which organochlorine compounds present in effluents from pulp mills using bleaching were responsible for the adverse impacts.*
- *To determine the short and long term impacts of organochlorine compounds on aquatic organisms.*

In order to achieve these objectives, the National Water Research Institute (NWRI) of Environment Canada and the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) of Fisheries and Oceans Canada, undertook research on the sub-lethal toxicity among fish populations exposed to pulp and paper effluents.[1] The research of interest took place between April 1988 and December 1996.

The work included the following components:

- Development of toxicity measurement methodologies
- Field studies
- Laboratory studies
- Development of chemistry, fate and effects models
- Information dissemination (drawing on the science).

The research outputs of interest are the results of the work and the studies described above. They include the methods and techniques developed, the publications of results and the presentations

[1] The work of Fisheries and Oceans is included because of the high degree of integration between the research efforts of the two departments in this area.

made to increase communication of those results. The knowledge elements contained in these outputs can be summarized as:

- Effluent testing methodologies.

- Toxicity of pulp mill effluents. Specifically, knowledge that Canadian pulp mill effluent causes sub-lethal toxic effects in fish.

- Role of organochlorine compounds and Adsorbable Organic Halogen (AOX). Specifically, knowledge that AOX is not a suitable parameter for measuring toxicity and that organochlorine compounds are not the sole source of toxic effects.

- Sources of toxicity within pulp mill processes. Including:

  - Evaporator and digester and cooking liquors from digesters
  - Condensates
  - Acids in secondary treatment
  - Additives (e.g., defoamers).

In addition to the direct outputs of the research, the R&D activities produced an additional output:

- Federal understanding of the worldwide knowledge base. Specifically, Environment Canada acquired an in-house understanding and expertise which could be used to understand and interpret the work of others as well as to integrate the knowledge for policy analysis.

The cost of NWRI's research, including GLLFAS contributions and those of universities and others, averaged $1.47 million per year over nine years, for a total of $13.2 million.

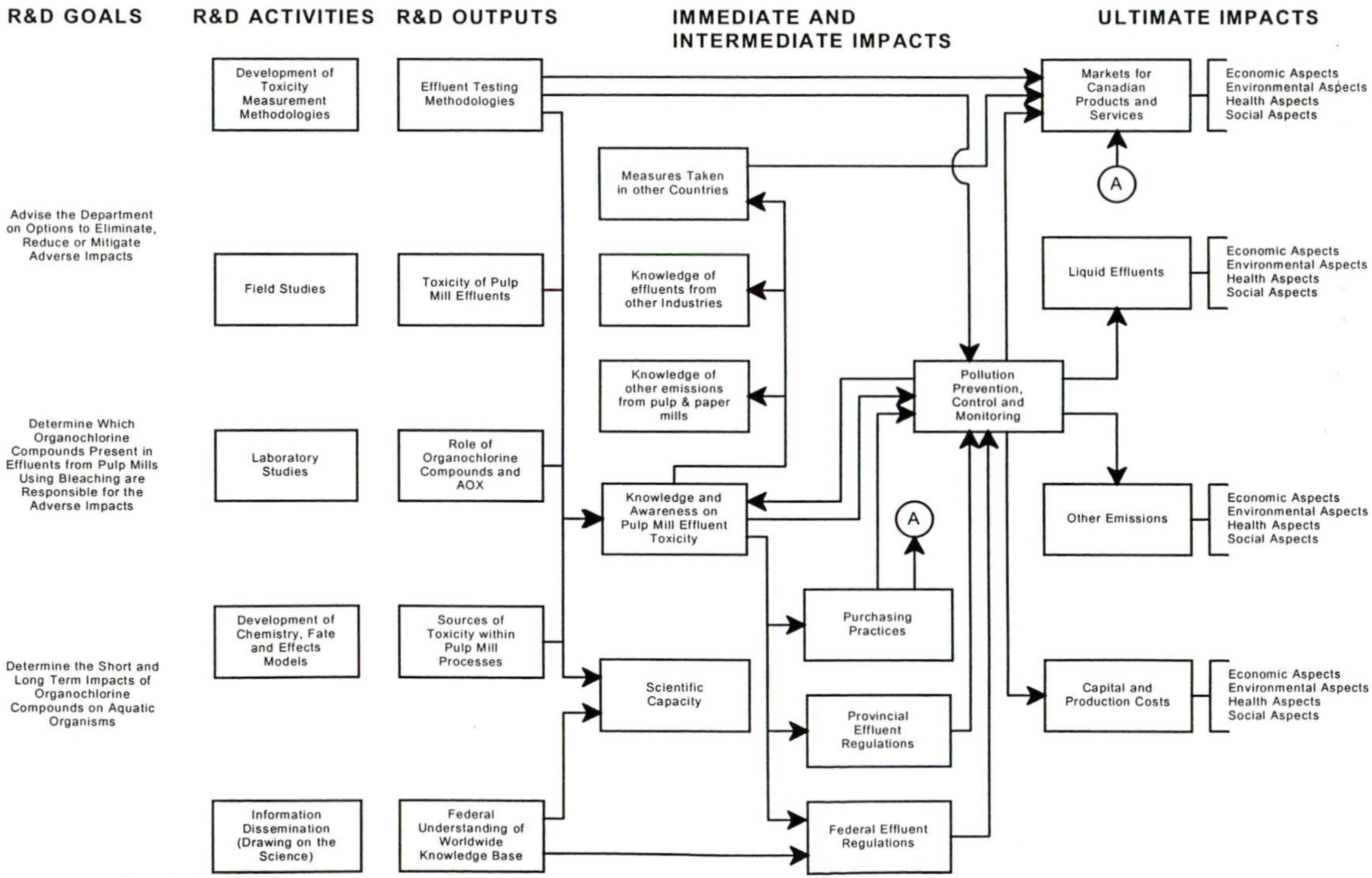
Identification of Impacts

The Impact Map (Figure E-1) identifies the potential impacts of the research that were considered.

The Map distinguishes between "immediate and intermediate" impacts and "ultimate" impacts. The former include the results of the research and their direct influence on government policies and programs and on public behaviour; while the latter are tangible impacts that have implications for the economy, the environment, society and/or human health.

The Map identifies nine immediate and intermediate impacts arising from the R&D outputs and four ultimate impacts, each of which has a number of socio-economic implications (including, potentially, economic, environmental, health and social aspects).

Figure E-1: Impact Map for Pulp & Paper Effluent Research



1. External influences not shown
2. For graphical simplicity, linkages between some elements are represented by (A)→

Based on the initial interviews and document reviews, a preliminary screening of the potential impacts was conducted to focus the study on the impact threads that were most significant and/or most likely to allow for credible description and attribution. On the basis of these criteria, three main threads were identified:

- **Thread 1.** The impacts on liquid effluents and other emissions, and the costs resulting from pollution prevention and control measures that were not required, because of changes to regulations on AOX that occurred as a result the knowledge on AOX provided by NWRI.

- **Thread 2.** The impacts on markets for Canadian pulp and paper products from changes in purchasing practices that occurred as a result of the knowledge on AOX provided by NWRI.

- **Thread 3.** The impacts on liquid effluents and other emissions, and costs from future changes to pollution prevention and control measures that are likely to be implemented as a result of NWRI knowledge concerning the sources of toxicity within pulp and paper processes.

As a result of this screening, a number of significant impacts, many of which are likely to be positive, were not considered in detail. They include:

- **Scientific Capacity**. This impact includes the technical infrastructure that was developed, including people, equipment and know-how (e.g., methodologies). It also includes access to the work of others and the development of absorptive capacity for such research. The infrastructure also creates other socio-economic impacts: it may lead to further productive R&D, it provides economic and social benefits by creating and maintaining Canadian jobs and expertise (e.g., training of graduates, keeping leading scientists in Canada), and it fosters a science based approach to problem solving and decision-making. Because such impacts are extremely difficult to define and attribute, they were not considered although they are anticipated to be positive.

- **Knowledge of other emissions from pulp and paper mills.** Although some knowledge has emerged, no applications have been identified to date. For this reason these impacts were not considered although they are anticipated to be positive.

- **Knowledge of effluents from other industries**. Although some knowledge has emerged, no applications have been identified to date. For this reason these impacts were not considered although they are anticipated to be positive.

- **Measures taken in other countries**. Although the results of such measures are likely to be tangible and measurable, they are not likely to have implications for Canadians. Because the main focus of the study was on the value of the R&D for Canadians, it was decided not to pursue these impacts, although they are anticipated to be positive.

- **Markets for Canadian Products and Services -- resulting from the commercialization of effluent testing methodologies.** To date, these methodologies have not found commercial applications. Consequently, their main impact will be felt by aiding future research and monitoring, which could eventually lead to improvements in water quality and associated costs. With the exception of the identification of the four potential sources of toxicity in pulp mill processes (included in thread 3), it is not possible to speculate on the nature of these potential impacts, although it is anticipated that they will be positive.

- **Markets for Canadian Products and Services (environmental technologies and services) -- resulting from measures not implemented in other countries, based on the research results concerning AOX.** Although this impact is not negligible, preliminary indications are that the Canadian share of the international market for the required technologies is small. For this reason, it was decided not to pursue these impacts. Because a significant portion of the research results involved discouraging the application of certain measures to eliminate AOX, most of which were being developed offshore, the overall negative impact on Canadian companies would likely have been small.

- **Markets for Canadian Products and Services (environmental technologies and services) -- resulting from measures taken in Canada or in other countries, based on the research results concerning possible sources of toxicity within mill processes.** The emerging conclusions concerning sources of toxicity within mill processes involve the application of relatively cheap maintenance and operation measures rather than new technologies. For this reason, these impacts were not considered although they are anticipated to be positive.

- **Pollution prevention, control and monitoring measures -- implemented as a result of changes in purchasing practices**. Although changes in purchasing practices are a potent incentive for the implementation of pollution prevention and control measures, indications are that, initially, Canadian industry would have had difficulty competing effectively in the markets that would have demanded AOX-free pulp. Consequently, regulations were assumed to be the driving force for the implementation of pollution prevention and control measures and it was assumed that purchasing practice played no role in this respect.

- **Pollution monitoring measures -- resulting from the development of effluent testing methodologies**. Preliminary indications are that the primary application of the testing methodologies remains in the research realm and that the influence of these methodologies on the design of industry monitoring programs has, so far, been relatively minor. For this reason, these impacts were not considered although they are anticipated to be positive.

Thread 1 -- AOX-Related Impacts on Liquid Effluents and Other Emissions, and Capital and Production Costs Avoided

The analysis indicated that:

- NWRI was the key contributor to the research result that AOX is not an appropriate parameter to regulate the toxicity of pulp and paper mill effluent.

- This result influenced regulators at the Federal and provincial levels in designing regulations. In the case of the Federal regulations, AOX was not included; in some provinces, AOX limits were not as stringent as they might otherwise have been.
- This saved the Canadian pulp and paper industry between $1.06 billion and $1.29 billion in capital and production costs. The best guess is a figure of $1.17 billion.

- Based on the analytical approach taken, the portion of these savings attributable to NWRI's research was between $640 million and $1.16 billion. The best guess is $880 million.

- Based on Environment Canada's view, there is no evidence that any environmental benefits were foregone as a result of not implementing AOX regulations.

Thread 2 -- AOX-Related Impacts on Markets for Canadian Pulp and Paper Products

The analysis indicated that:

- NWRI was the key contributor to making consumers aware that AOX is not an appropriate parameter to measure the toxicity of pulp and paper mill effluent.

- This result influenced pulp consumers (particularly in Europe) to moderate their preference for TCF pulp and to continue purchases of ECF and conventional pulp.

- Since Canada produces virtually no TCF pulp, this allowed Canadian pulp mills to maintain a larger share of the European market than they otherwise would have.

- The value of the market that was protected was between $323 million and $1.20 billion. The best guess is a figure of $762 million.

- Based on the analytical approach taken, the portion of this market protection attributable to NWRI's research was between $194 million and $1.08 billion. The best guess is $572 million.

Thread 3 -- Impacts on Liquid Effluents and Other Emissions (and Capital and Production Costs) from Changes to Pulp Mill Processes

The analysis indicated that:

- NWRI was the key contributor to the research conclusion that Canadian pulp mill effluent (whether bleached with chlorine or not) causes sub-lethal toxic effects analogous to effects first observed in Sweden.

- NWRI has been and continues to be a key contributor to the development of test methods to evaluate the toxicity of effluents.

- NWRI was a significant contributor to the identification of several potential sources of toxicity within mill processes, including:

  - black liquor from digesters
  - digester condensates
  - breakdown of resin acids in secondary treatment
  - use of certain additives (e.g., defoamers).

- Pollution prevention and control measures which may be implemented, at least partially in response to this research, would improve effluent and ambient water quality and could contribute significantly to mitigating or eliminating a variety of sub-lethal toxic effects in fish (including reproductive effects). There is no evidence of any net environmental costs or benefits associated with changes to other emissions.

Economic, Environmental, Health and Social Aspects

With respect to economic and social aspects, the focus is on the AOX-related impacts on markets for Canadian pulp and paper products and the AOX-related capital and production costs avoided.

The analysis indicates that the markets preserved and costs avoided as a result of NWRI research resulted in an increase to GDP of between $231 million and $962 million. The best guess is $546 million. The research also resulted in the creation (preservation) of between 3,900 and 15,700 FTE (person years of employment). The best guess is 9000 FTE .

With respect to environmental and health aspects, the focus is on changes to pulp mill processes that could be undertaken to reduce or eliminate sources of toxicity.

The analysis concluded that it was not possible to fully describe or quantify either the changes or their potential effects. However, the following general statements can be made:

- Although only a little is known about the effects, and they have not been decisively linked to population or community impacts, there are good reasons to believe that such impacts may exist and could be alleviated, at least partially, by the implementation of specific pollution prevention and control measures.

- The pollution prevention and control measures may also have the effect of reducing the risk of unknown human health impacts that could be associated with the sub-lethal effects in fish.
- The cost of implementing the pollution prevention and control measures is unknown, but appears to be modest.

- **Conclusions**

The analysis conducted indicates that the R&D on pulp mill effluent toxicity conducted by NWRI during the period 1988 to 1996 was responsible for cost savings to the Canadian pulp and paper industry in the order of $880 million (based on the Best Guess scenario). It was also responsible for protecting markets for the products of the pulp and paper industry worth approximately $572 million (also based on the Best Guess scenario).

These savings and markets protected resulted in an increase to GDP of $546 million and the creation (preservation) of 9000 person years of employment. Based on research costs of $13 million, these benefits represent measurable economic returns of approximately $42 of GDP per dollar of research and one person-year of employment per $1,444 of research expenditure.

In addition the research has identified potential sources of toxicity within mill processes. These findings may lead to measures that yield future environmental benefits (as yet unclear) at modest cost.

The study noted that the results of the analysis were more sensitive to changes in some assumptions than others, including most notably, the assumptions concerning the attribution of the research results to NWRI, the assumptions underlying the costing of AOX reduction technologies, the assumptions regarding the regulatory possibilities in key provinces (Ontario and Québec), and the assumptions relating to possible changes in European purchasing practices.

The study also noted a number of observations concerning the methodology that could be useful in the conduct of future evaluations.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Environment Canada retained the services of Marbek Resource Consultants and Secor Inc. to help identify, describe and measure the impacts of Environment Canada (EC)'s Research and Development (R&D).

The project is one of eight projects included in the *Business Plan for Managing R&D at Environment Canada, 1996 to 1997* and responds, in part, to the 1994 *Auditor General's Report* and the 1996 *Federal Strategy for Science and Technology*, which suggested a need for increased accountability for R&D results. The project is directed by a Steering Committee composed of members of each of the Department's Services (see Appendix A).

The objectives of the project are to provide a rigorous documented evaluation of the impacts of two programs and to validate an approach to the evaluation of such impacts. The two chosen programs are: pulp and paper effluent R&D and stratospheric ozone depletion R&D.

In choosing two different projects, the Steering Committee sought to examine research activities with different characteristics. In the case of ozone, the research contributed to an international effort leading to global action, whereas in the case of pulp and paper, research was focused on the content of imminent regulations. The case studies also represent efforts of two different research groups within the department and different aspects of the environment. The expectation of the Committee was that, as a result of its direct link to regulatory policy, pulp and paper research was more likely to have had significant quantifiable economic impacts. By selecting case studies with these different characteristics, it was hoped to learn more about the feasibility and approaches to measuring the impact of R&D.

1.2 THIS REPORT

This report deals with the first of those case studies: pulp and paper effluent R&D. It seeks to document the socio-economic impacts of the research (including the ultimate economic, environmental, social and health effects). It does not attempt to assess the quality of the research nor does it seek to determine the effect of the research on subsequent R&D. It does, however, deal with all the impacts of the R&D that are considered significant, whether intended or not.

Section 2 describes the approach used.

Section 3 provides a summary of the science and describes the pulp and paper effluent R&D program being assessed in terms of its objectives, activities, outputs and costs. Section 3 also establishes the boundaries of the research, in terms of time, location and activities to be included.

Section 4 introduces the Impact Map for the research; describes the various immediate and ultimate impacts in general terms; and establishes the priority impact threads for more detailed analysis.

Section 5 reviews each of the impacts included in the priority impact threads. Each impact is described and attributed to the R&D (or the preceding impacts, as the case may be). Scenarios are developed to evaluate the impacts.

Section 6 integrates the results of Section 5 and assesses the overall economic, environmental, health and social implications of the ultimate impacts of the R&D. Where possible, these impacts are valued in monetary terms. Otherwise, they are described in terms of biophysical or social effects (either quantitative or qualitative). Various combinations of scenarios are examined and a sensitivity analysis is performed. Based on this overall assessment and the costs of the R&D, general conclusions concerning value for money are presented.

Section 7 identifies some general conclusions about the impacts of the R&D and the lessons learned in the process of the evaluation.

2. APPROACH

2.1 GENERAL

The challenges in evaluating the socio-economic impacts of public sector R&D include the usual methodological problems in identifying and attributing results. In addition, the evaluation of public sector R&D has to contend with the fact that the research is often directed towards producing common property benefits (which can be difficult to identify and assess) and the fact that these impacts are often at the end of a long chain of complex intermediate impacts involving government policies and changes in the behaviour of firms and individuals.

The current state of the art in R&D impact measurement has been described by Williams.[2] It involves the use of methods such as benefit-cost analysis, econometric analysis, modified peer review, bibliometric analysis, case histories, user and client surveys. The view described by Williams is that there have been sufficient advances in methodologies to conduct credible "partial" assessments of R&D impacts provided that certain criteria are met. He suggests that the extent to which the research results would have been available without the specific R&D and the extent to which the impacts are attributable to the existence of these results are two key factors in deciding whether an assessment should be attempted. Williams also favours research that is directed towards industry and whose results are applied within a fairly short time period.

The nature of the pulp and paper R&D (and the ozone R&D) is such that the applications are primarily in policy realms and they are applied over an extended period of time. Furthermore, the attribution of the research results and the impacts is not necessarily high in all cases. Given these realities, the challenge is to develop new approaches that can provide credible measures of impacts, while recognizing the inherent limitations of the exercise.

Given the project's dual objectives of evaluating the impacts and validating the approach, it is appropriate to provide some detail on the approach that was developed.[3]

2.2 IMPACT MAPPING

The heart of the approach is the development of an "Impact Map" which is a graphical representation of the linkages between the outputs of the R&D and the various policy and behavioural changes leading to ultimate impacts and socio-economic implications (see Figure 2.1).

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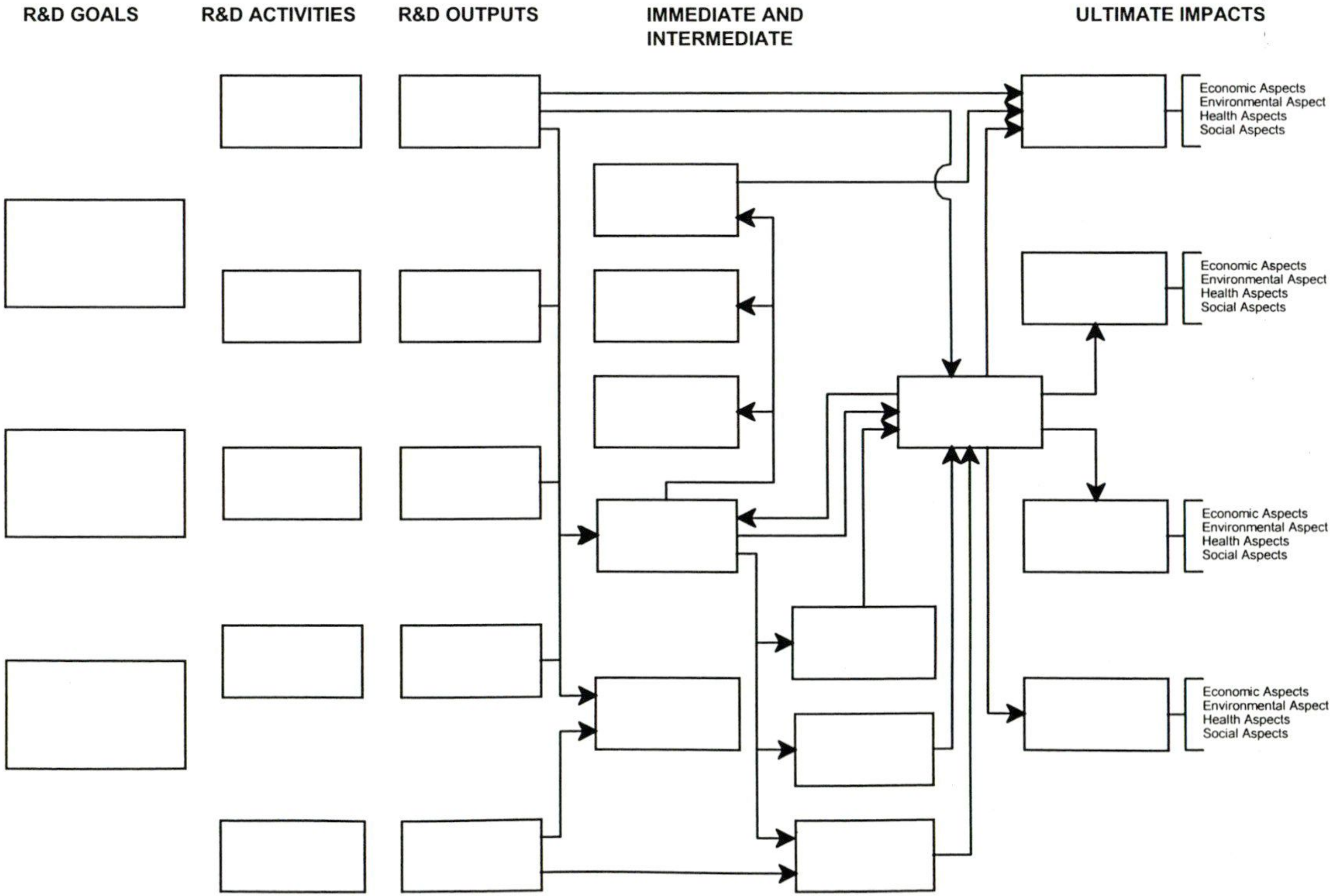
[2] Williams, D. (ARA Consulting Group Inc.). *Measuring the Impacts of Public Investment in R &D.* Paper presented at the Natural Sciences and Engineering Research Council of Canada, Ottawa, December 2, 1996.

3 The approach is described in more detail in:. Marbek Resource Consultants and Secor Inc. *Measuring the Environmental and Socio-Economic Impacts of Environment Canada's R&D -- Project Plan.* March 27, 1997.

Figure 2.1 - Impact Map



The aim is to provide an explicit and transparent description of the chains (or threads) by which the impacts of the R&D are realized. A significant amount of effort was expended in producing and improving the Impact Map to provide the most accurate and useful representation possible. This evolved into an iterative process which began with a Map proposed by the project team and concluded with an amended Map that took into account the information gained through interviews and document reviews. In the process, certain impact threads were identified as priorities for analysis, because of the likelihood of significant impact or the likelihood that those impacts could be credibly identified.

2.3 SEQUENCE OF STEPS

- **Step 1 -- Develop Initial Impact Map**

The first step was to develop a working draft of the impact map based on the initial information provided by the Steering Committee and the National Water Research Institute (NWRI).

- **Step 2 -- Develop Questionnaire**

Based on the Impact Map, a series of questions were identified to establish the nature of the impacts (immediate and ultimate) and the attribution of those impacts to the R&D. For the attribution of the research results, the approach was to seek a proportionate assignment of a share of the knowledge base (in terms of specific knowledge elements) to the research being evaluated. For example, participants were asked to suggest what percentage of the credit should be attributed to NWRI for determining that AOX was not a suitable parameter for measuring toxicity. For the other impacts, the approach was to identify the incremental impact by postulating scenarios of what would likely have happened in the absence of the preceding impacts (e.g., knowledge, regulations or behavioural changes). For example, participants were asked to speculate on what the regulations might have looked like if the knowledge on AOX had not been available.

- **Step 3 -- Conduct Interviews**

To answer the questions, a series of interviews were conducted and documents were reviewed. The interview subjects and documents were identified by the Steering Committee, by the Project Team, and by some of the interview subjects themselves. An Interview Guide was developed to focus each interview on the key questions that were relevant to the subject's experience and relevant knowledge (see Appendix B). During the process, this Guide was amended several times to respond to a number of competing needs, including:

- Keeping the interview short, simple and straightforward
- Providing an opportunity for interview subjects to tell the story
- Focussing interview subjects on the questions of interest
- Eliciting specific views on attribution of impacts
- Eliciting speculation on "what if" scenarios.

Approximately 30 interviews were conducted for the pulp and paper case (see Appendix C).

Unsurprisingly, the result of those interviews was a large amount of subjective information, some of it contradictory.[4] The interviews were very useful in understanding the full story of the impacts (and completing the Impact Map) and getting a general idea of the impacts and their attribution; however, many of the questions were left without explicit answers. This was due to a reluctance on the part of interview subjects to assign credit in anything more than general terms, and a further reluctance to speculate on what might have happened in the absence of the R&D (or what might happen in the future).

- **Step 4 -- Review Reference Documents**

Approximately 15 documents were reviewed for the pulp and paper case (see Appendix D). These documents provided the information necessary to identify the key knowledge elements involved and some indication of the sources of the knowledge for purposes of assigning credit. The documents also provided a reasonably good, if somewhat dated, source of information on the capital and production costs involved with different scenarios and the direct and indirect economic effects of some of those scenarios. It was a challenge to obtain information on markets for pulp and paper products and on the future plans of industry for pollution prevention and control measures.

- **Step 5 -- Analysis**

Given the gaps in the data available for analysis, it was not possible to generate accurate and absolute answers to the various questions needed to establish the impacts and their attribution. Consequently, the approach evolved to the development of credible scenarios. Using summaries of the interviews and the reference documents, the Project Team developed the following elements of analysis:

- A reasonably accurate description of what actually happened (in terms of regulations and costs)
- A best estimate of the relative contributions of the different researchers to the R&D results (based on an overall assessment of the interview results), together with reasonable high impact and low impact scenarios for NWRI's contribution
- A series of credible scenarios of what might have happened in the absence of the knowledge, the regulations, etc., together with estimates of the probability of each scenario (where possible)
- A qualitative assessment of what might happen in the future as a result of emerging impacts.

Using these estimates, the Project Team was able to describe and in some cases quantify the socio-economic impacts of the R&D under various scenarios. Although there is significant uncertainty associated with the results, it is believed that, at a minimum, they provide a good

[4] The Pulp and Paper Effluent Case Study Interim Report provides additional detail on the challenges faced in obtaining reliable and useful information. Marbek Resource Consultants and Secor Inc. *Measuring the Impact of Environment Canada's R&D, Pulp and Paper Effluent Case Study -- Interim Report.* May 2, 1997.

indication of the value for money of the R&D and can be used, albeit with caution, in science policy and planning.

3. DESCRIPTION OF THE R&D PROGRAM

This section summarizes the science and describes the goals, activities, outputs and costs of the pulp and paper effluent R&D performed by Environment Canada's National Water Research Institute (NWRI), in association with the Department of Fisheries and Oceans' Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS).

3.1 SUMMARY OF THE SCIENCE ON THE TOXICITY OF PULP AND PAPER EFFLUENTS

Pulp and paper mills discharge a variety of substances as by-products of their processes. Under pressure to protect the aquatic environment, they have progressively reduced discharges of substances causing biological and chemical oxygen demand (BOD and COD), total suspended solids (TSS), and acute lethality to aquatic biota. Concern about the potential for toxicity of chlorinated organic compounds has also prompted limitations on dioxins and furans, chlorinated phenols, and entire classes of substances, most notably Adsorbable Organic Halogen (AOX).

Chlorinated compounds are formed during bleaching and alkaline extraction of wood fibre to remove residual lignin after pulping. Elemental chlorine, chlorine dioxide (ClO_2) oxygen and ozone can be used to oxidize lignin, thereby removing colour. The intensity of fibre colour, the characteristics of the pulp and other factors determine the amount of bleach used, and the amount and type of by-products. Pulp mills that use chlorine dioxide as opposed to elemental chlorine for bleaching are referred to as "Elemental Chlorine Free (ECF)", whereas mills that use no chlorine are labelled "Totally Chlorine Free (TCF)".

Prior to 1984, most field studies of the effects of pulp mill effluent focused on benthic communities and acute lethality in fish. In 1984-85, a major study in Sweden demonstrated that fish in the Baltic Sea exposed to effluent from bleached kraft pulp mills showed chemical contamination, various sub-lethal physiological responses, and impaired reproduction. Swedish scientists concluded that these effects were due to the effluent, specifically to the presence of chlorinated compounds as measured by AOX. Sweden subsequently began to use AOX as a licensing or regulatory parameter, an initiative adopted by several other countries, and announced their intention to eventually eliminate AOX discharged in pulp mill effluents. An expert panel reviewed these results and suggested that they might not apply in North America due to the unique ecological conditions of the Baltic Sea, process upsets at the Swedish mill using chlorine bleaching, and the choice of an inappropriate reference unbleached mill. The panel concluded that similar effects were unlikely to occur at North American mills.

Canadian studies in rivers and lakes, during the period of 1988-96, found effects that were analogous to those observed in Sweden. However, the Canadian studies did not demonstrate a link between levels of AOX and the responses measured, although the effects of specific chlorinated compounds could not be ruled out. In addition, responses were found in fish exposed to effluent from unbleached pulp mills, indicating that non-chlorinated compounds could cause these effects. Subsequent Canadian research has focused on identifying the sources of toxicity within mill processes.

3.2 R&D GOALS

The original goal of the R&D was:

- ***To advise the Department on options to eliminate, reduce or mitigate adverse impacts from pulp and paper effluent.***

As the Department's policies were being developed, and regulations were being developed, two additional goals emerged:

- ***To determine which organochlorine compounds present in effluents from pulp mills using bleaching were responsible for the adverse impacts.***

- ***To determine the short and long term impacts of organochlorine compounds on aquatic organisms.***

The R&D on pulp and paper effluent began in the mid 1980s with the general objective of characterising the impact of pulp and paper effluent in order to advise Environment Canada and Fisheries and Oceans on options to eliminate, reduce or mitigate adverse impacts. With the publication of the Swedish results and a heightened concern about organochlorines, policy-makers became more specific in specifying the scientific information they needed. Hence, beginning in 1988, the goal became one of assisting the Department in deciding what was the appropriate limit which should be imposed on AOX discharges (the fact that AOX should be regulated was generally accepted at the time). With the discovery in 1991 of evidence that AOX was not a good predictor of the sub-lethal effects, the goals shifted towards the identification of the specific organochlorine compounds responsible and their impact. Later, with the discovery that many of the sub-lethal effects could be caused by non-chlorinated compounds from elsewhere in the pulp making process, the emphasis shifted again to the identification of the responsible compounds, whether they were chlorinated or not. This part of the work became known as the search for "compound X". More recently, in recognition of the complexity of effluent composition and the effects, the goal has begun to shift towards the identification of practical design and process changes that would result in a minimum impact mill. The research has also supported Environment Canada's Environmental Effects Monitoring program by characterizing typical impacts and providing monitoring tools.

3.3 R&D ACTIVITIES

In assessing the impacts of the pulp and paper effluent R&D, it is essential that the boundaries of the activities to be included be clearly defined so that the impacts and associated resources are related to the same body of work.[5]

[5]The boundaries refer to the R&D per se, not to the impacts associated with the R&D. Thus, for instance, R&D on effluents from other industries will not be analysed. On the other hand, contributions to the knowledge of those effluents obtained in the process of researching pulp and paper effluent could be analysed.

In selecting boundaries, we have included only those activities which are central to the research effort and cannot be disassociated from it. We have selected a start date that corresponds to a significant milestone in the character of the research program. Finally, since the R&D is ongoing, we have selected an end date for the research that is as current as possible, while respecting the limitations of data collection and analysis.[6]

Thus, the body of research assessed consists of research on the sub-lethal toxicity among fish populations exposed to pulp and paper effluents conducted by the National Water Research Institute (NWRI) of Environment Canada and the Great Lakes Laboratory for Fisheries and Aquatic Sciences of Fisheries and Oceans, between April 1988 and December 1996.[7]

The development of pollution prevention and control technology for pulp and paper mills by industry and others, research on human health effects at Health Canada and elsewhere, and development of measurement technology for organochlorines are not included.

The start date was chosen to correspond with the beginning of focussed activity in this area in response to international research and concern about the toxicity of effluents from pulp mills using chlorine in bleaching in 1988. Later start dates were rejected in order to capture the most significant activities associated with the program.

The research included the following components:

- **Development of toxicity measurement methodologies**. This included laboratory and field trials to devise appropriate effluent testing methodologies.
  - Application of passive samplers for monitoring effluent chemicals toxic to fish.
  - Development of cell culture techniques as a substitute for whole-fish tests and as a tool to rapidly screen large numbers of effluent and pure compounds.
  - Development of methodology for assessing the effects of multiple stressors on fish populations.
  - Development and validation of in vivo and in vitro tests of reproductive impairment in fish, stress responses in benthic invertebrates, and mutagenic and genotoxic effects in microbes and fish.
  - Development of bioassay-driven methods for isolating toxic components of complex mixtures.
  - Development of Toxicity Identification Evaluation (TIE) procedures that incorporate mechanistically based endpoints for reproduction.

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[6] Similarly, the end date refers to the R&D per se, not to the impacts associated with the R&D. Thus, for instance, R&D carried out after the end date will not be analysed. On the other hand, impacts associated with R&D carried out before the end date will be analysed, even if the impacts occurred after the end date.

[7] The work of Fisheries and Oceans is included because of the high degree of integration between the research efforts of the two departments in this area.

- **Field studies**. This included studies to determine the sub-lethal effects of pulp and paper effluents on fish and studies to determine the effects of various factors on the toxicity of pulp and paper effluents. A list of the key studies and associated references is provide in Table 3.1.

  - Evaluation of mutagenicity and genotoxicity in fish and other vertebrates exposed to pulp mill effluents.
  - Identification of the impacts of process changes and waste treatment improvements on the reproductive performance of fish.
  - Comparison among pulping technologies of the impacts of pulp mill wastes.

- **Laboratory studies**. This included studies to determine the effects of various factors on the toxicity of pulp and paper effluents.

  - Identification of chemicals in pulp mill effluents causing increased activity of liver mixed function oxygenase (MFO) enzymes (chemical metabolism) and reproductive impairment (chemical toxicity) in fish.
  - Evaluation of mutagenicity and genotoxicity in fish and other vertebrates exposed to pulp mill effluents.
  - Application of TIE approaches to complex mixtures and effluents to isolate and identify the chemicals responsible for biological effects.

- **Development of chemistry, fate and effects models.**

  - Description of the transport, fate and effects of effluent chemicals in receiving water ecosystems.

- **Information dissemination (drawing on the science)**. This included the preparation of associated publications and presentations to specific audiences of Canadian and foreign scientists, regulators, consumers and other interested groups.

Table 3.1
Key Studies Undertaken by NWRI/GLLFAS

Year	Location	Description	References
1988 - ongoing	Jackfish Bay, Lake Superior, Ontario	Observed reproductive responses in fish (white sucker) downstream of primary treated effluents from bleached kraft mill.	Munkittrick, K.R., C.B. Portt, G.J. Van Der Kraak, I.R. Smith and D.A. Rokosh. 1991. Impact of bleached kraft mill effluent on population characteristics, liver MFO activity and serum steroid levels of a Lake Superior white sucker (*Catostomus commersoni*) population. Can. J. Fish. Aquat. Sci. 48: 1371-1380. McMaster, M.E., G.J. Van Der Kraak, C.B. Portt, K.R. Munkittrick, P.K. Sibley, I.R. Smith and D.G. Dixon. 1991. Changes in hepatic mixed function oxygenase (MFO) activity, plasma steroid levels and age at maturity of a white sucker (*Catostomus commersoni*) population exposed to bleached kraft pulp mill effluent. Aquat. Toxicol. 21: 199-218
1989-92	St-Maurice River, Québec	Confirmed reproductive responses at second bleached kraft mill with primary treatment.	Hodson, P.V., M. McWhirther, K. Ralph, B. Gray, D. Thivierge, J. Carey, G. Van Der Kraak, D.M. Whittle, and M.C. Levesque. 1992. Effects of bleached kraft mill effluent on fish in the St. Maurice River, Quebec. Environ. Toxicol. Chem. 11: 1635-1651. Gagnon, M.M., J.J. Dodson, and P.V. Hodson. 1994a. Ability of BKME (bleached kraft mill effluent) exposed white suckers (*Catostomus commersoni*) to synthesize steroid hormones. Comp. Biochem. Physiol. 107C: 265-273. Gagnon, M.M., J.J. Dodson, and P.V. Hodson. 1994b. Seasonal effects of bleached kraft mill effluent on reproductive parameters of white sucker (*Catostomus commersoni*) populations of the St. Maurice River, Quebec, Canada. Can. J. Fish. Aquat. Sci. 51: 337-347.
1990	Jackfish Bay, Lake Superior, Ontario	Observed continued physiological responses with secondary treatment. Responses disappeared quickly when mill was shut down.	Munkittrick, K.R., G.J. Van Der Kraak, M.E. McMaster and C.B. Portt. 1992a. Response of hepatic mixed function oxygenase (MFO) activity and plasma sex steroids to secondary treatment and mill shutdown. Environ. Toxicol. Chem. 11: 1427-1439.
1990	Jackfish Bay, Lake Superior, Ontario	Confirmed responses in second species (lake whitefish).	Munkittrick, K.R., M.E. McMaster, C.B. Portt, G.J. Van Der Kraak, I.R. Smith and D.G. Dixon. 1992b. Changes in maturity, plasma sex steroid levels, hepatic MFO activity and the presence of external lesions in lake whitefish exposed to bleached kraft mill effluent. Can. J. Fish. Aquat. Sci. 49: 1560-1569.

1990-93	Spanish River (Espanola), Ontario	Observed reproductive response from low AOX mill with secondary treatment.	Servos, M., J. Carey, M. Ferguson, G. Van Der Kraak, H. Ferguson, J. Parrott, K. Gorman and R. Cowling. 1992. Impact of a modern bleached kraft mill with secondary treatment on white suckers. Water Pollut. Res. J. Can. 27: 423-437.
1991	Ten Mill Study, Ontario	Observed responses both in mills using chlorine and mills not using chlorine.	Robinson, R.D., J.H. Carey, K.R. Solomon, I.R. Smith, M.R. Servos and K.R. Munkittrick. 1994. Survey of receiving water environmental impacts associated with discharges from pulp mills. 1. Mill characteristics, receiving water chemical profiles and lab toxicity tests. Environ. Toxicol. Chem. 13: 1075-1088. Munkittrick, K.R., G.J. Van Der Kraak, M.E. McMaster, C.B. Portt, M.R. van den Heuvel and M.R. Servos. 1994a. Survey of receiving water environmental impacts associated with discharges from pulp mills. 2. Gonad size, liver size, hepatic EROD activity and plasma sex steroid levels in white sucker. Environ. Toxicol. Chem. 13: 1089-1101. Servos, M.R., S. Huestis, D.M. Whittle, G.J. Van Der Kraak and K.R. Munkittrick. 1994. Survey of receiving water environmental impacts associated with discharges from pulp mills. 3. Polychlorinated dioxins and furans in muscle and liver of white sucker (*Catostomus commersoni*). Environ. Toxicol. Chem. 13: 1103-1115. van den Heuvel, M.R., K.R. Munkittrick, G.J. Van Der Kraak, M.E. McMaster, C.B. Portt, M.R. Servos and D.G. Dixon. 1994. Survey of receiving water environmental impacts associated with discharges from pulp mills. 4. Bioassay-derived 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalent concentration in white sucker (*Catostomus commersoni*) in relation to biochemical indicators of impact. Environ. Toxicol. Chem. 13: 1117-1126.
1992	Laboratory Study on fathead minnows using effluent from Espanola, Ontario	Confirmed that effluent was capable of causing responses in a laboratory setting.	Robinson, R.D. 1994. Evaluation and development of laboratory protocols for predicting the chronic toxicity of pulp mill effluents to fish. Univ. of Guelph, Ph.D. Thesis

3.4 R&D OUTPUTS

The research outputs of interest are the results of the work and the studies described above. They include the methods and techniques developed, the publications of results (over 100) and the presentations made to increase communication of those results. The knowledge elements contained in these outputs can be summarized as contributions to the following research results:

- **Effluent testing methodologies.**

- **Toxicity of pulp mill effluents**. Specifically, knowledge that Canadian pulp mill effluent causes sub-lethal toxic effects in fish.

- **Role of organochlorine compounds and AOX**. Specifically, knowledge that AOX is not a suitable parameter for measuring toxicity and that organochlorine compounds are not the sole source of toxic effects.

- **Sources of toxicity within pulp mill processes**. Including:

    - Black liquor from digesters
    - Digester condensates
    - Acids in secondary treatment
    - Additives (e.g., defoamers).

In addition to the direct outputs of the research, the R&D activities produced an additional output:

- **Federal understanding of the worldwide knowledge base**. Specifically, Environment Canada acquired an in-house understanding and expertise which could be used to understand and interpret the work of others as well as to integrate the knowledge for policy analysis.

3.5 COSTS

NWRI has estimated the direct costs associated with the research activities, including the costs borne by the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) and other contributors. A summary of these costs, which total approximately $13 million, is presented in Table 3.2. More detail is provides in Appendix E.

With respect to other costs, NWRI estimates that a few thousand fish (mostly white suckers) were harvested for testing. There were no known disruptions to pulp mill operations associated with the R&D and no other costs were identified.

Table 3.2
Summary of Costs of R&D on Pulp and Paper Effluent Toxicity
($million)

Year	Environment Canada	Fisheries and Oceans Canada	Other		Total
			ISTC (University)[8]	Other External[9]	
88/89	738				738
89/90	713				713
90/91	817	286		15	1,118
91/92	733	227	170		1,130
92/93	787	334	140		1,261
93/94	970	410	170		1,550
94/95	1,835	574	190	148	2,747
95/96	1,356	588	200	105	2,249
96/97	1,164	471		77	1,712
Total	9,113	2,890	870	346	13,219

[8]These figures represent resources provided by Industry Canada as matching funding for universities.

[9]These figures include external sources of funding such as Mott Foundation Fellowships, the Canadian Electrical Association and funding for cooperative projects under agreements with pulp producers such as Noranda Forest Products.

4. IDENTIFICATION OF IMPACTS AND LINKAGES

4.1 THE IMPACT MAP

As expected, the Impact Map for the pulp and paper effluent R&D evolved considerably as additional knowledge and insights were accumulated from the interviews, the document reviews and the analysis. The final version of the Map is shown in Figure 4.1.

The Map distinguishes between "immediate and intermediate" impacts and "ultimate" impacts. The former include the results of the research and their influence on policy and behaviour; while the later are tangible impacts that have implications for the economy, the environment, society and/or human health.

The Map identifies nine immediate and intermediate impacts arising from the R&D outputs and four ultimate impacts, each of which has a number of socio-economic implications (including, potentially, economic, environmental, health and social aspects). Of the thirteen impacts identified, five stand out as intended impacts of the R&D program (shown in bold in Figure 4.1), while the rest, though important, were not deliberate in the view of the researchers.[10] Twelve of the impacts are direct applications of the research and one (scientific capacity) is an indirect impact which recognizes that scientific discovery is not a linear process and that the knowledge and skills acquired in the process of conducting this R&D may have other applications.

A summary of the impacts follows:

4.1.1 Immediate and Intermediate Impacts

- **Knowledge and awareness on pulp mill effluent toxicity**. The principal immediate impact of the R&D was a contribution to the worldwide knowledge base concerning various aspects of the sub-lethal toxicity of pulp and paper effluent (as described above) and awareness of this knowledge. In addition, the development, by NWRI, of testing methodologies is leading to additional knowledge through the application of those methodologies in research, or in environmental effects monitoring programs implemented by pulp and paper companies. The new methods are currently being applied by NWRI in studies of the toxicology of refinery and petrochemical effluents and in a new research program into the environmental effects of endocrine-disrupting chemicals.

- **Scientific capacity**. Indirectly, the R&D also contributed to building a technical infrastructure, including people, equipment and know-how. This infrastructure creates socio-economic impacts in several ways: it may lead to further productive R&D and it provides economic and social benefits by maintaining Canadian jobs and expertise, which, in part, can be used to assimilate the R&D of others.

[10] It is arguable that some of these impacts are legitimate policy objectives and therefore intended R&D impacts, by association with the objective of supporting good policy.

- **Knowledge of other emissions from pulp and paper mills**. Although focused on liquid effluents, the work necessarily involved understanding the nature and magnitude of the various material flows and transformations inside mill processes. This knowledge may be useful in characterizing air and solid emissions and understanding the mechanisms which produce these emissions. It is also possible that the work on aquatic toxicology could help establish some of the effects of these emissions.

- **Knowledge of effluents from other industries**. In the process of investigating the transport, fate and effects of pulp and paper effluents, knowledge may have been gained on constituents present in other effluents and on relevant transport processes in receiving waters. This will likely have applications in the analysis of the effects of effluents from industries such as chemicals, mining, petroleum refining and manufacturing.

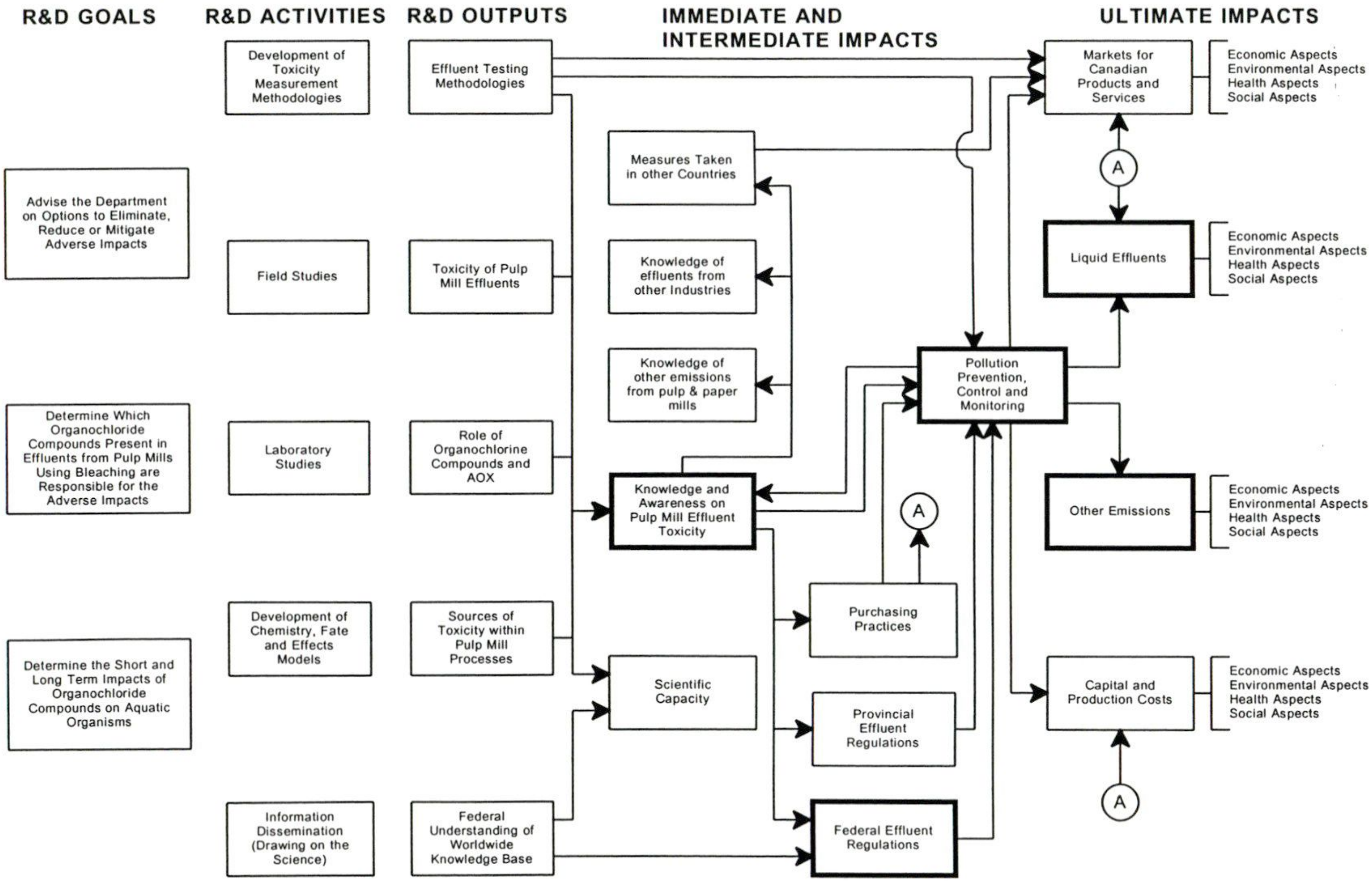
- **Measures taken in other countries**. The knowledge of pulp and paper effluent toxicity and awareness of it can be expected to be used by policy-makers in other countries. The result should be better-designed regulations and other instruments, and cost-effective pollution prevention and control measures in those countries. These will have corresponding effects on the environment and the economy in those countries and could have global repercussions.

- **Federal effluent regulations**. The main purpose of the R&D was to inform policy-makers within Environment Canada so that cost-effective measures could be taken to mitigate or eliminate adverse impacts resulting from pulp and paper effluents. The overall worldwide knowledge base (including the NWRI contributions to it) were used by policy-makers along with the direct advice of NWRI scientists in interpreting the knowledge. These had an influence on the nature of the regulations that were promulgated and may influence future actions by Environment Canada.

- **Provincial effluent regulations**. Although NWRI did not set out to influence provincial regulators, the knowledge was used and NWRI's efforts to explain the Federal approach also had an influence. The impact affected the nature of provincial regulations that were promulgated and could include future actions by provincial regulators.

- **Purchasing practices**. In addition to affecting regulators, the knowledge, and the awareness of it, would have had an effect on the purchasing practices of consumers of pulp and paper products. To the extent that the decisions of these consumers were affected by environmental factors and specifically the toxicity of pulp and paper effluents, there would have been voluntary changes reflecting the perceived relative environmental profile of Canadian pulp and paper products.

Figure 4.1 - Impact Map for Pulp and Paper Effluent Research



Notes: 1. External influences not shown
2. For graphical simplicity, linkages between some elements are represented by Ⓐ→
3. Intended Impacts are represented by ▭

- **Pollution prevention, control and monitoring measures**. The decision of pulp and paper companies to implement such measures and the nature of the measures implemented were and are influenced by many factors, including:
  - Regulations (federal and provincial)
  - The purchasing practices of customers
  - The existence of convincing knowledge about impacts (and awareness of it)
  - The existence of cost-effective technological solutions.

Specific methodologies for effluent testing may also be adopted directly by companies for the purposes of monitoring effects, voluntarily or as mandated by regulations.

4.1.2 Ultimate Impacts

- **Markets for Canadian Products and Services**. Various markets may have been, or could be affected by the R&D. The markets for pulp and paper products were influenced by changes in the purchasing practices of consumers and could have been influenced by trade restrictions based on environmental considerations. The development of effluent testing methodologies could open up new markets for companies that provide consulting services or monitoring equipment, or for NWRI to establish joint ventures with such companies. The implementation of pollution prevention, control and monitoring measures (in Canada and internationally) might also create opportunities for Canadian consultants and suppliers of environmental technologies.

- **Liquid Effluents.** Changes in pollution prevention or control measures would have had an effect on the characteristics of pulp and paper effluents. In addition, changes in purchasing practices could have modified the product mix of pulp and paper companies, with corresponding changes in effluents. Future changes in either of these influences may also affect water quality.

- **Other Emissions**. Changes in pollution prevention or control measures for liquid effluent (past, present or future) would also have an effect on the other emissions of pulp and paper mills. For example, control measures might shift substances from the water to the air or solid waste streams and pollution prevention measures could result in overall reductions in all waste streams. As with liquid effluents, other emissions may be affected by changes to the product mix, influenced by changes in purchasing practices.

- **Capital and Production Costs**. Changes in pollution prevention or control measures involve process changes, new equipment and different inputs. These changes would have had, and may yet have, cost implications for producers and consumers. In addition, changes in purchasing practices might also have had cost implications for consumers.
  Although an attempt has been made to identify all possible impacts (even those whose nature is unclear), it is possible, and perhaps likely, that there are other impacts (past, present and future) that have not been identified.

4.2 SIGNIFICANT IMPACT THREADS

Based on the initial interviews and document reviews, a preliminary screening of the potential impacts was conducted to focus the study on the impact threads that were most significant and/or most likely to allow credible description and attribution. On the basis of these criteria, three main threads were identified (see Figure 4.2 and the individual representations in Section 5):

- **Thread 1.** The impacts on liquid effluents and other emissions, and the costs resulting from pollution prevention and control measures that were not required, because of changes to regulations on AOX that occurred as a result the knowledge on AOX provided by NWRI.
- **Thread 2.** The impacts on markets for Canadian pulp and paper products from changes in purchasing practices that occurred as a result of the knowledge on AOX provided by NWRI.
- **Thread 3.** The impacts on liquid effluents and other emissions, and costs from future changes to pollution prevention and control measures, that are likely to be implemented as a result of NWRI knowledge concerning the sources of toxicity within pulp and paper processes.

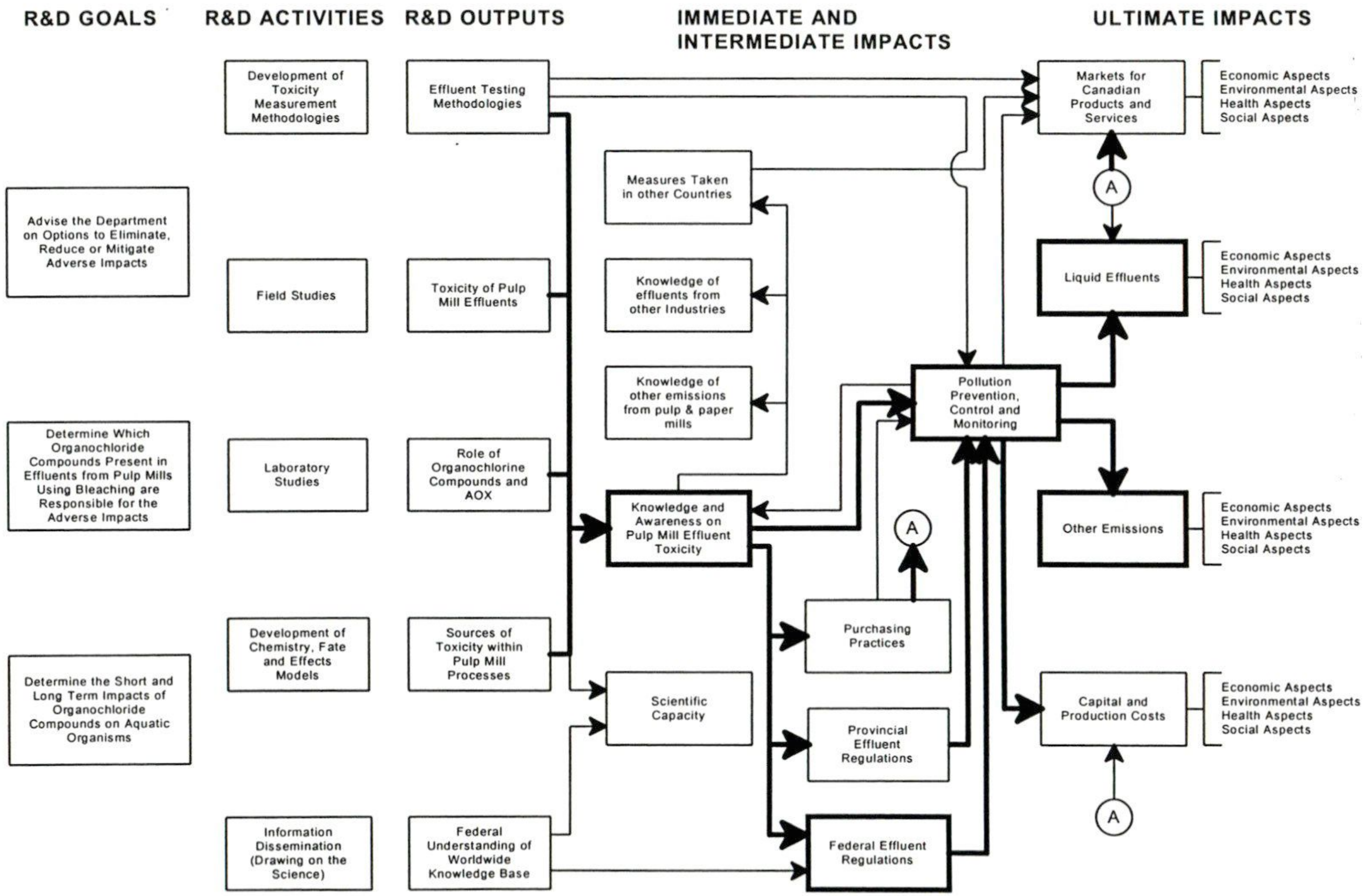
The impacts that are **not** a part of one of the significant impact threads have been eliminated from further consideration for the following reasons:

- **Scientific Capacity**. This impact includes the technical infrastructure that is developed, including people, equipment and know-how (e.g., methodologies). It also includes access to the work of others and the development of absorptive capacity for such research. The infrastructure also creates other socio-economic impacts: it may lead to further productive R&D, it provides economic and social benefits by creating and maintaining Canadian jobs and expertise (e.g., training of graduates, keeping leading scientists in Canada), and it fosters a science based approach to70 problem solving and decision-making. Because such impacts are extremely difficult to define and attribute, they are not considered further, although they are anticipated to be positive.

- **Knowledge of other emissions from pulp and paper mills.** Although some knowledge has emerged, no applications have been identified to date. For this reason the impacts are not considered further, although they are anticipated to be positive.

- **Knowledge of effluents from other industries**. Although some knowledge has emerged, no applications have been identified to date. For this reason the impacts are not considered further, although they are anticipated to be positive.

Figure 4.2 - Principal Impact Threads for Pulp and Paper Effluent Research



Notes:
1. External influences not shown
2. For graphical simplicity, linkages between some elements are represented by (A)
3. Principal impact threads are represented by →
4. Intended impacts are represented by ▭

- **Measures taken in other countries.** Although the results of such measures are likely to be tangible and measurable, they are not likely to have implications for Canadians. Because the main focus of the study was on the value of the R&D for Canadians, it was decided not to pursue these impacts, although they are anticipated to be positive.

- **Markets for Canadian Products and Services -- resulting from the commercialization of effluent testing methodologies.** To date, these methodologies have not found commercial applications. Consequently, their main impact will be felt by aiding future research and monitoring, which could eventually lead to improvements in water quality and associated costs. With the exception of the identification of the four potential sources of toxicity in pulp mill processes (included in thread 3), it is not possible to speculate on the nature of these potential impacts, although it is anticipated that they will be positive.

- **Markets for Canadian Products and Services (environmental technologies and services) -- resulting from measures not implemented in other countries based on the research results concerning AOX.** Although this impact is not negligible, preliminary indications are that the Canadian share of the international market for AOX reduction technologies is small.[11] For this reason, it was decided not to pursue these impacts. Because a significant portion of the research results involved discouraging the application of certain measures to eliminate AOX, most of which were being developed offshore, the overall negative impact on Canadian companies selling to these markets would likely have been small.

- **Markets for Canadian Products and Services (environmental technologies and services) -- resulting from measures taken in Canada or in other countries, based on the research results concerning possible sources of toxicity within mill processes.** The emerging conclusions concerning sources of toxicity within mill processes involve the application of relatively cheap maintenance and operation measures rather than new technologies. For this reason, it was decided not to pursue these impacts although they are anticipated to be positive.

- **Pollution prevention, control and monitoring measures -- implemented as a result of changes in purchasing practices**. Although changes in purchasing practices are a potent incentive for the implementation of pollution prevention and control measures, indications are that, initially, Canadian industry would have had difficulty competing effectively in the markets that would have demanded AOX-free pulp and therefore could not have justified investments on this basis. Consequently, we have decided to treat regulations as the driving force, and assume that changes in purchasing practices had no effect on the implementation of pollution prevention and control measures.

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[11] For a variety of reasons, the Canadian share of the domestic market may be more significant. These indirect impacts are considered in Section 6.2.1.

- **Pollution monitoring measures -- resulting from the development of effluent testing methodologies**. Preliminary indications are that the primary application of the testing methodologies remains in the research realm and that the influence of these methodologies on the design of industry monitoring programs has, so far, been relatively minor. For this reason, it was decided not to pursue this impact although it is anticipated to be positive.

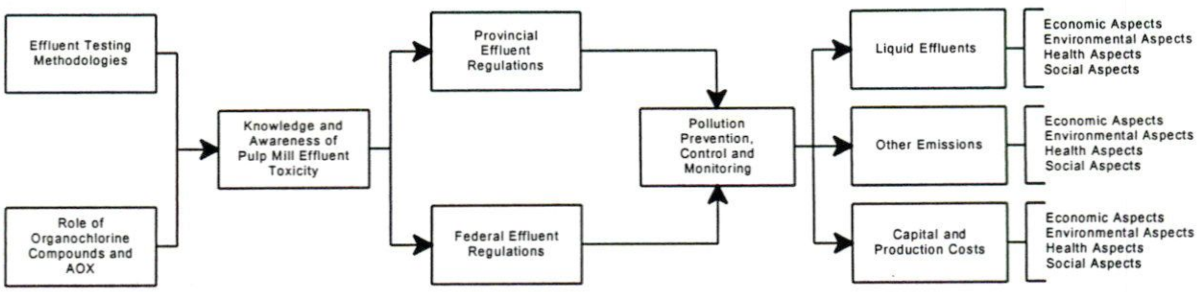
It should be noted that the impacts not analysed are, for the most part, real and not just hypothetical. Although they are difficult if not impossible to describe and quantify, some may be significant. Because most are positive, the following analysis is considered to provide a conservative view of the benefits of the NWRI R&D.

5. DESCRIPTION OF IMPACTS AND INDIVIDUAL ATTRIBUTION

This section documents the result of efforts to characterize and attribute the impacts associated with the principal impact threads:

- **Thread 1.** The impacts on liquid effluents and other emissions, and the costs resulting from pollution prevention and control measures that were not required, because of changes to regulations on AOX that occurred as a result the knowledge on AOX provided by NWRI.
- **Thread 2.** The impacts on markets for Canadian pulp and paper products from changes in purchasing practices that occurred as a result of the knowledge on AOX provided by NWRI.
- **Thread 3.** The impacts on liquid effluents and other emissions, and costs from future changes to pollution prevention and control measures, that are likely to be implemented voluntarily as a result of NWRI knowledge concerning the sources of toxicity within pulp and paper processes.

5.1 THREAD 1 -- AOX-RELATED IMPACTS ON LIQUID EFFLUENTS AND OTHER EMISSIONS AND CAPITAL AND PRODUCTION COSTS AVOIDED



Thread 1 is illustrated in Figure 5.1. It postulates that NWRI research led to the discovery that AOX was not a suitable parameter for regulation. As a result, various Canadian jurisdictions (Federal and provincial) modified their proposed regulations. In some cases, AOX was eliminated as a regulatory option; in other cases, plans for more stringent limits were set aside. This, in turn, meant that pulp and paper mills did not incur the capital and production costs associated with the pollution prevention and control measures that would have been needed to meet the AOX regulations. Not implementing pollution prevention and control measures might also have had an impact on liquid effluents and other emissions.

The linkages are:

- Impact of NWRI research outputs on knowledge and awareness of AOX and the toxicity of organochlorines
- Impact of knowledge and awareness of AOX and the toxicity of organochlorines on AOX

regulations
- Impact of AOX regulations on pollution prevention and control measures
- Impact of pollution prevention and control measures on liquid effluents and other emissions
- Impact of pollution prevention and control measures on capital and production costs.

These linkages are considered, in turn, in the following subsections.

5.1.1 Immediate and Intermediate Impacts: Impact of NWRI Research Outputs on Knowledge and Awareness of AOX and the Toxicity of Organochlorines

The knowledge and awareness at issue is that:

> *"AOX is not a suitable regulatory parameter and substances other than organochlorines are responsible for observed sub-lethal effects".*

According to NWRI, the conclusion emerged from research undertaken in the period 1988 to 1991, beginning at Jackfish Bay, on the north shore of Lake Superior and in the St. Maurice River, Québec. Although the evidence was becoming clear by 1991, publication was delayed because the efforts of key scientists were devoted to providing advice in support of Environment Canada's policy development. This culminated with the 1991 release of the *Priority Substances Assessment Report on Effluent from Pulp Mills Using Bleaching*, which concluded that it was not possible to establish a scientific basis for setting a federal AOX level; and the decision not to regulate on the basis of AOX.

This preeminent role of NWRI is supported by the historical account provided by Van Nijnatten and Leiss.[12] Their account singles out NWRI with the following statement in a two-page conclusion:

> *Moreover, those who have remained committed to regulating via the AOX parameter have not addressed the pointed scientific critiques, by NWRI's John Carey and others, directed at the AOX-based approach.*

A review of reference documents indicates that the view that AOX was not suitable emerged in the period 1990 to 1994, with the first publications being presented at the First International Conference on Environmental Fate and Effects of Bleached Pulp Mill Effluents in Saltsjobaden, Sweden in November 1991. Four NWRI papers that were presented at that conference dealt with the issue:

- Hodson, P.V., D. Bussieres, M.M. Gagnon, J.J.Dodson, C.M. Couillard and J. H. Carey.

[12] VanNijnatten, D. L., Leiss, W., and Hodson, P.V. (Draft 1997). *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada*. Kingston, Ontario.

Review of biochemical, physiological, pathological and population responses of white sucker (Catostomus commersoni) to BKME in the St. Maurice River, Quebec. Environmental fate and effects of bleached pulp mill effluents. Proceedings of a SEPA Conference held at the Grand Hotel Saltsjobaden, Sweden, Nov. 19-21, 1991. pp 261-269.

- K. R. Munkittrick. *Recent North American studies of bleached kraft mill impact on wild fish.* Environmental fate and effects of bleached pulp mill effluents. Proceedings of a SEPA Conference held at the Grand Hotel Saltsjobaden, Sweden, Nov. 19-21, 1991. pp. 347-356.

- T. G. Williams, M. R. Servos, J. H. Carey and D. G. Dixon. *Biological response monitoring for pulp mill effluents.* Environmental fate and effects of bleached pulp mill effluents. Proceedings of a SEPA Conference held at the Grand Hotel Saltsjobaden, Sweden, Nov. 19-21, 1991. pp. 391-394.

- A. Chung, H. Cook and D. Halliburton. *An overview of pulp and paper mill effluent control in North America and Scandinavia.* Environmental fate and effects of bleached pulp mill effluents. Proceedings of a SEPA Conference held at the Grand Hotel Saltsjobaden, Sweden, Nov. 19-21, 1991. pp 7-9.

Although the subject of AOX had been addressed in earlier publications (1989-1991), these earlier references arguably did not address the issue in relation to fish or they did not provide convincing evidence to support the hypothesis. The first relevant publications, other than NWRI's, include:

- Pesonen, M. and Andersson, T. 1992. *Toxic effects of bleached and unbleached paper mill effluents in primary cultures of rainbow trout hepatocytes.* Ecotoxicol. Env. Saf. 24:63-71.

- Lehtinen, K.-J. 1992. *Environmental effects of chlorine bleaching -- Facts neglected?* Paperi Ja Puu -- Paper and Timber 74 no. 9: 715-719.

These papers provided independent confirmation of the claims of NWRI and helped solidify a consensus on the conclusion that AOX was not a suitable parameter to measure toxicity.

The extent to which the knowledge and awareness should be attributed to NWRI was addressed by seven interview subjects. Their views are summarized as follows:

- NWRI and the Finnish researchers share the credit.

- Before NWRI's work, the Industry said there were no effects; and the Swedish work suggested that there were, and AOX was to blame. NWRI resolved the issue.

- NWRI was mainly responsible for the conclusion that AOX did not correlate with toxicity. Paprican and NCASI were other contributors.

- The NWRI work allowed for broader criteria for environmental impacts. No one else was doing similar work at that time.
- NWRI deserves 2/3 of the credit; Paprican is responsible for the other third.
- NWRI confirmed the work of Paprican and NCASI.
- The AOX conclusion came from NWRI in collaboration with university researchers.

Although the information collected is somewhat contradictory, the preponderance of evidence suggests that NWRI was the main source of the research results that generated the knowledge and awareness in question. Based on all of the available information, the following attribution estimate is suggested:

Contribution of NWRI to the knowledge and awareness that AOX is not a suitable regulatory parameter and substances other than organochlorines are responsible for observed sub-lethal effects:

- Low impact scenario: 60%
- Best guess scenario: 75%
- High impact scenario: 90%.

5.1.2 Immediate and Intermediate Impacts: Impact of Knowledge and Awareness of AOX and the Toxicity of Organochlorines on AOX Regulations

To identify the impact of the knowledge on regulations, it is necessary to compare, in each jurisdiction, the existing regulations with hypothetical regulations reflecting what would have happened in the absence of the knowledge. In this case, the exercise was complicated the by the following factors:

- The uncertain influence of some of the other factors which might have played a role (politics, economic impact).
- The extended timeframe over which the issue might have evolved (the AOX limit might have become more stringent over time).
- A reluctance to second guess the motives of governments or to reveal emerging thinking on a controversial issue.
- A general reluctance on the part of interview subjects to speculate when faced with significant uncertainty.

Nevertheless, interview subjects were asked to speculate on the decision-making environment and to suggest possible outcomes. The views expressed and the evidence in the reference documents were interpreted by the Project Team and assembled into regulatory possibilities, each of which was assigned a likelihood based on the available information. The result is presented in Table 5.1.

Table 5.1
Hypothetical AOX Regulations

AOX REGULATIONS			
Jurisdiction	**Expected AOX regulations in absence of NWRI research (kg/t)**	**Likelihood(%)**	**Actual Regulation (kg/t)**
Federal	2.5	10	nil (2.5)[13]
	1.5	80	
	0	10	
BC	0	100	0[14]
Alberta	1.0-1.5	90	0.8-3.0[15]
	<0.8[16]	10	
	0	0	
Ontario	0.8	10	0.8[17]
	<0.8[22]	20	
	0	70	
Québec	0.8	20	0.8[18]
	<0.8[22]	40	
	0	40	
Atlantic	n/a		n/a[19]

Source: Marbek Resource Consultants (for likelihood of regulations in the absence of NWRI research) and Environment Canada (for actual regulations).

[13] Although the Federal Government did not regulate AOX, the regulations on BOD, acute toxicity and dioxins and furans were expected to lead to a level of AOX of not more than 2.5 kg/t. These regulations have since been shown to reduce AOX levels below 1.5 kg/t.

[14] Since BC adopted a zero regulation in spite of NWRI, no other scenarios are possible. Were BC to change its' approach, a reevaluation of the impact would be warranted.

[15] Alberta does not regulate AOX but uses AOX as a licensing parameter. Current limits range from 0.8 to 3.0 kg/t.

[16] This scenario is defined as the best available technology (BAT) scenario, while continuing to use ClO_2. In new mills, this technology would be expected to result in levels of 0.3 kg/t. Older mills would achieve 0.6 kg/t.

[17] Ontario regulations imposed limits of 2.5 kg/t by February 1994, 1.5 kg/t by December 1995, and 0.8 kg/t by December 1999.

[18] Québec regulations impose a limit of 0.8 kg/t by December 2000.

[19] The Atlantic provinces chose to rely on the Federal regulations.

Although it is difficult to predict what implementation schedule might have been associated with hypothetical regulations, it seems likely that some delay would have been included for meeting the more stringent limits. For the purposes of this analysis, we make the conservative assumption that zero AOX limits, where applicable, would not have been imposed until 2000. This means that pulp producers would have benefited from advances in technology that occurred in the period leading up to the present.

Support for our estimates of the likelihood of the AOX limits presented in Table 5.1 comes from the literature and from the interviews. We dealt separately with Federal and Provincial regulations.

Federal Regulations

The following references provided support for the development of possibilities for the Federal regulations:

- Environment Canada. 1991. *Effluents from pulp mills using bleaching. Canadian Environmental Protection Act -- Priority Substances List Assessment Report No. 2.* Environment Canada and Health and Welfare Canada, Ottawa. This report concluded that there was little evidence linking AOX to effects. Because it specifically mentions AOX and was released at the same time as the Dioxins and Furans regulations it provides a good indication that AOX regulations might otherwise have been considered.
- VanNijnatten, D. L., Leiss, W., and Hodson, P.V. (Draft 1997). *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada.* Kingston, Ontario. This report suggests that the Federal regulations did not include an AOX regulation because other regulations would reduce AOX to below 2.5 kg/t and NWRI research indicated that further AOX reductions were unlikely to solve the problem of residual effects. This also supports the idea that AOX might otherwise have been regulated.
- N. McCubbin Consultants Inc. June 1990. *Economic Impact of Proposed Regulation of Pulp and Paper Industry -- BOD, TSM and Toxicity; Organochlorines (AOX); Dioxins and Furans.* Environment Canada, Ottawa. This 1990 examination of the economic impact of proposed Federal regulations (including an option of 1.5 kg/t for AOX) provides concrete evidence that an AOX regulation of 1.5 kg/t was seriously considered as late as 1990.
- Bemda Management Services and David C. Graham & Associates. June 1990. *The Impact of New Environmental Regulations on the Competitiveness of the Canadian Pulp and Paper Industry.* Environment Canada, Ottawa. This report suggests that the likely Federal standard would have been 1.5 kg/t though there still was a debate about the cost and necessity of achieving this level. This statement further supports the likelihood of a 1.5 kg/t limit.

In addition, the question of Federal regulations was addressed by four interview subjects. Their views are summarized as follows:

- Regulation of AOX was discussed at Environment Canada in late 1989 or early 1990. At that time the proposed level was 1.5 kg/t. There was no serious consideration of a zero limit at that time; however, there was political momentum in that direction. Because the technology at the time did not provide for levels below 1.5 kg/t without going to zero, a decision on more stringent regulation would likely have led to a limit of zero. Knowledge that an intermediate option was possible emerged too late to have affected the regulation.
- The work by NWRI showed the inappropriateness of AOX as a regulatory parameter and as a result a decision was taken not to address organochlorines federally, using an AOX regulation.
- Without NWRI, the Federal government would have regulated AOX.
- AOX was going to be included in the Federal regulations. The proposed level would have been 1.5 kg/t. Zero was not a possibility.
- Without NWRI, the Federal regulations would have been no more stringent that 1.5 kg/t and probably 2.5 kg/t.

Although the information collected is again contradictory, the preponderance of evidence suggests that in the absence of NWRI's research, 1.5 kg/t was the most likely level and that there were slight possibilities that the regulation would be zero or that there would have been no regulation.

Provincial Regulations

In the case of the provinces, no documented information was obtained concerning potential regulations; however the subject was addressed by eight interview subjects. Their views are summarized as follows:

- The NWRI findings were instrumental in assisting the lobbying efforts of industry in several provinces.
- NWRI findings were considered by B.C. but they decided on a zero limit anyway.
- The NWRI research was not a big influence on Alberta's decision to use an AOX limit of 1.0-1.5 kg/t as a licensing parameter.
- The NWRI findings were the sole reason for the Ontario decision not to require zero emissions.
- Without NWRI, zero AOX may have become a regulatory requirement in Ontario.
- Without the NWRI findings, it is possible that Québec would have imposed a limit of

zero. Economic studies were also a factor.

- Without NWRI, Québec's regulation would almost certainly have been more stringent and very possibly, it would have been zero.

- AOX is not included in Atlantic provinces' regulations because they decided to rely on the Federal regulations.

Based on this information and the fact that several provinces chose to regulate AOX in spite of the NWRI findings, a zero level was considered more likely for the provincial scenarios. In addition, because of their regulations were developed later, many of the provinces benefited from additional information which would have allowed an intermediate regulatory option based on improved Best Available Technology (BAT) using chlorine dioxide, which could have achieved levels of AOX of less than 0.8 kg/t.

5.1.3 Immediate and Intermediate Impacts: Impact of AOX Regulations on Pollution Prevention and Control Measures

The 1991 Federal regulations, which took effect in 1994, set new limits on pulp and paper effluent to control BOD, acute toxicity, dioxins and furans. AOX was not included as a regulatory parameter. In the years that followed, the provinces added their own regulations, most of which did include AOX limits. Mills were thus faced with the task of implementing pollution prevention and control measures to meet the most stringent of the two regulations (usually provincial).

In order to evaluate the impact of the changes to the Regulations brought upon by NWRI, we need to consider other factors and how they might have affected the implementation of pollution prevention and control measures (with and without the research results).

Despite NWRI's research, mills might have voluntarily chosen to implement measures for a variety of other reasons. However, the evidence is that, for the most part, mills have not gone beyond the requirements of Ontario and Québec regulations (0.8 kg/t) to any significant degree. For example, the average mill AOX effluent level in Canada was 0.9 kg/t in 1995[20]. Since the most significant cost differences are associated with achieving levels below 0.8 kg/t, we assume for the purposes of this analysis that regulations were the sole driver for the measures actually implemented.

With respect to measures that might have been implemented in the absence of the research results, it is possible that changes in European purchasing practices could have induced mills to implement measures to reduce AOX (beyond the requirements of the regulations). However, indications are that Canadian industry would have had difficulty moving quickly to zero levels of

[20] CPPA 1996 Reference Tables.

AOX (the only level that would have mattered) and that they would have had further difficulties in competing with European mills on a cost basis. For these reasons, we have chosen to capture this impact as lost market share rather than introduce a further driver for pollution prevention and control measures.

Each of the AOX levels defined in Section 5.1.2 corresponds to a combination of measures; each of which, in turn, has corresponding costs. Table 5.2 provides typical combinations.

Table 5.2
Pollution Prevention and Control Measures

AOX Regulation (kg/t)	**Measures**
Dioxins and Furans	Secondary Treatment >70% ClO_2 Substitution or Oxygen Delignification
1.0-1.5[21]	Secondary Treatment>70% ClO_2 Substitution orOxygen Delignification
0.8	Secondary Treatment100% ClO_2 Substitution orOxygen Delignification
<0.8 (BAT)	100% ClO_2 SubstitutionOxygen Delignification Extended CookingLow Kappa Factor Operation
0	Oxygen DelignificationOzoneHydrogen Peroxide

Source: N. McCubbin Consultants Inc

It is worth noting that these combinations reflect current (1997) knowledge. Although the technologies were largely available at the time regulations were being developed, their effectiveness in reducing AOX was underestimated. Consequently, pulp producers might have over-invested in order to match expected AOX discharges to the regulations. In addition, the technology for producing zero AOX (TCF) was considered risky at the time.

5.1.4 Ultimate Impacts: Impact of Pollution Prevention and Control Measures on Liquid Effluents and Other Emissions

Although the Federal government concluded that AOX regulations were not warranted, it is worth considering whether the measures associated with meeting such regulations might have

[21] Although it was not known at the time the regulations were imposed, the measures taken to comply with the dioxins and furans regulations also decreased AOX below 1.5 kg/t.

had some benefit with respect to the quality or quantity of liquid effluents and other emissions. To examine this question, we rely on the results of the research described in Section 5.1.1.

The main conclusions are that:

- Sub-lethal effects are present in fish not exposed to chlorine bleaching effluent.[22]
- Residual effects in pulp mills are not correlated with AOX.[23]

Although these results are widely accepted, it has been suggested that, since the toxicology of organochlorines is not well-understood, there may yet be some impacts associated with their presence and that the precautionary approach would warrant their elimination.[24]

John Carey, of NWRI, responds to this suggestion as follows:[25]

> *"The precautionary approach may have some validity when we have no observable effects and want to be careful, but in this case, we have observable effects that will not be eliminated by the proposed reductions. Whether they will be eliminated by eliminating the organochlorines depends completely on the means by which we eliminate the organochlorines. It can just as easily be imagined that the elimination of organochlorines will increase the effects, if they or if the compounds causing the effects are partially decomposed during bleaching. The precautionary basis for eliminating organochlorines is based on inappropriate models of organochlorines (such as PCBs or DDT) that do not compare chemically to the vast majority of the organically bound chlorine present in effluents.*

Environment Canada's position was stated in the CEPA Assessment Report of 1991: "AOX as a measurement does not provide estimates of the potential toxicity, persistence, or bioaccumulation (of pulp mill effluent) in the aquatic environment."

From this statement and the evidence collected by NWRI, we can infer that some mills with low AOX will be comparatively environmentally-friendly whereas others will not (the same goes for mills with high AOX).

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[22]Hodson, P.V., Carey, J.H., Munkittrick, K.R. and Servos, M.R. 1995. *Canada and Sweden -- Contrasting Regulations for Chlorine Discharge from Pulp and Paper Industries.* Environment Canada and Fisheries and Oceans Canada, Burlington.

[23]Ibid.

[24]VanNijnatten, D. L., Leiss, W., and Hodson, P.V. (Draft 1997). *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada.* Kingston, Ontario.

[25]Ibid.

Overall, Environment Canada is not aware of any information indicating that net environmental benefits were foregone as a result of the Department's decision not to use AOX as a regulatory parameter.

Consequently, for the purposes of this study, impacts on the quality of effluents and emissions are not considered.

5.1.5 Ultimate Impacts: Impact of Pollution Prevention and Control Measures on Capital and Production Costs

More stringent regulations would have required pulp and paper mills to make additional capital investments. These investments would have changed the operating costs of pulp and paper mills in Canada. To pay for the cost of compliance on both the capital and operating sides, pulp mills would have had to reduce profits, or reduce costs (including labour costs), or increase prices, or seek government assistance, or some combination of the four.

In this section, estimates for what those costs would have been are developed.

To accomplish this task, two steps are required:

- ***Step 1*** -- Costs must be estimated for each of the **technology combinations** associated with the possible AOX regulations.
- ***Step 2*** -- Those costs must be applied to the **regulatory possibilities** identified in each of the provinces in Section 5.1.2. (even though the Federal Government chose not to regulate AOX, provincial regulations may have imposed AOX limits).

Step 1 -- Costs for AOX Technology Combinations

Several reports were consulted to establish the costs of technologies to control AOX emissions.

In studying the impacts of the proposed 1991 Federal regulations, McCubbin Consultants prepared mill by mill estimates of compliance costs for regulations on BOD, acute toxicity, dioxins and furans.[26] Unfortunately, similar studies on the costs of meeting other possible AOX regulations were not conducted for individual mills across Canada. Another McCubbin study, prepared for the Ontario Ministry of Environment, did examine individual mills in that province, but it did not estimate the costs of going to zero AOX.[27] A study by H.A. Simons Consulting

[26] McCubbin Consultants, Economic Impact of Proposed Regulation of Pulp and Paper Industry, June 1992: Tables A1.9 and A3.4

[27] Ontario Ministry of the Environment, Best available Technology for the Ontario Pulp and Paper Industry, a report prepared by McCubbin Consultants, February 1992, p 262.

Engineers examined a zero AOX scenario for the BC Ministries of Environment and Economic Development, but this study used hypothetical representative mills in place of actual mills and it dealt with BC mills only.[28]

Although the Simons study could be used to generate estimates for other Canadian mills, indications were that the costs proposed in this study were outdated, in that they underestimated the potential effectiveness of the technologies in reducing AOX and significantly overestimated the costs. To obtain more realistic estimates, a new study was commissioned from McCubbin Consultants (Appendix F).

This 1997 McCubbin study conducted a mill by mill assessment of capital and operating costs using a model developed for the U.S. Environmental Protection Agency (EPA). It calculated costs over and above the costs associated with meeting the 1991 Federal regulations. These costs were calculated in 1993 Canadian dollars and are based on the present (1997) knowledge of the effectiveness of the technologies available in 1993, and cost data from roughly that time period. We believe this is justified, because of our assumption that most of the required investments would not have been made before 1997. This is a conservative approach; had we used costs as anticipated in 1993, estimates would have been substantially higher.

McCubbin's estimates of capital costs were used as is. Annual operating costs were projected out 20 years and discounted at 15 percent per year to 1993 dollars. Results are summarized in Table 5.3.[29]

[28] H.A. Simons Ltd., Assessment of Industry Costs to Meet British Columbia's New AOX Regulations, June 1992.

[29] For comparison purposes, all costs and revenues in this report are expressed in 1993 dollars. To convert values from other years, a discount rate is applied. The discount rate (15 percent in this case) compensates for the following factors: inflation, uncertainty (risk) and the time value of money (preference to enjoy the benefit today rather than tomorrow). The discount rate is the rate at which it is believed that the value of money will decline over time as a result of these factors.

Table 5.3
Estimate of AOX Control Costs for Regulatory Possibilities[30]
(in addition to the costs associated with meeting the 1991 Federal Regulations)

Province	Number of Mills	AOX Regulation (kg/t)	Capital Costs ($ million 1993) [31]	Operating Costs ($ million per year) [31]	Discounted Operating Costs ($ million 1993) [31]	Total Costs ($ million 1993)
BC	15	zero	1413	64	159	1572
Prairie	5	1.5	nil	nil	nil	nil
		<0.8	214	(7)	(16)	198
Ontario	8	0.8	10	5	21	31
		<0.8	875	(10)	(25)	850
		zero	588	25	62	650
Québec	7	0.8	15	4	14	29
		<0.8	794	(7)	(18)	776
		zero	541	23	56	597
Atlantic	4	1.5	nil	nil	nil	nil
		zero	283	12	29	312

It is interesting to note that these estimates indicate that meeting a limit of zero AOX using TCF technology would in most cases be cheaper than installing best available technology using chlorine dioxide (assuming the difference in operating costs is discounted at 15 percent).

For comparative purposes, we have presented in Appendix G costs based on the 1992 Simons report referred to above. These numbers are substantially higher than the 1997 McCubbin numbers presented in Table 5.3 and Appendix F.

The substantial difference between these two estimates is attributable to several factors:

- Knowledge of the effectiveness of the technology obtained since 1992.
- Possible reductions in technology costs in the period between the collection of source data for the two reports.
- The fact that the BC mills may not be representative of Canadian mills generally and require more significant costs than their counterparts in other provinces.
- The more conservative approach adopted by McCubbin.

For the purposes of this analysis, the more conservative estimates derived from the 1997

[30]The possibilities are outlined in Table 5.1. Note that the Federal regulations apply in the Atlantic Region.

[31]Brackets indicate cost savings.

McCubbin report will be used.

For individual mills, McCubbin estimated the margin of error to be plus or minus 25 percent. For national and provincial totals, the margin is estimated to be plus or minus 10 percent. Consequently, our scenarios will be based on a range of plus or minus 10 percent.

Step 2 -- Application of Costs to Regulatory Possibilities

In order to calculate the cost savings associated with not implementing AOX-related measures, the above costs need to be applied to the regulatory possibilities identified in Table 5.1. The results are shown in Table 5.4. In order to make the calculations, the most stringent regulations (Federal or provincial) are used. This means that the Federal regulations have an impact only in the Atlantic provinces.

For each jurisdiction, the savings are calculated by subtracting the cost associated with the actual regulation imposed (taken from Table 5.3) from the cost associated with each of the hypothetical regulations identified in the jurisdiction (also taken from Table 5.3).

Table 5.4
Cost Savings Due to Knowledge of AOX -- by Jurisdiction

Jurisdiction	Hypothetical (without the research)			Actual		Hypothetical Cost Savings ($million 1993)
	Regulation (kg/t)	Likelihood (%)	Cost ($million 1993)	Regulation (kg/t)	Cost ($million 1993)	
BC	0	100	1,572	0	1,572	nil
Prairie	1.0-1.5	90	0	1.0-1.5	0	nil
(based on	<0.8	10	198			198
Alberta scenarios)	0	0	404			404
Ontario	0.8	10	31	0.8	31	nil
	<0.8	20	850			819
	0	70	650			619
Québec	0.8	20	29	0.8	29	nil
	<0.8	40	776			747
	0	40	597			568
Atlantic	2.5	10	0	nil	0	nil
(Federal	1.5	80	0			0
regulation)	0	10	312			312

These estimates can be combined to produce the overall cost savings for Canadian industry (see Table 5.5). In calculating these savings, we include three scenarios:

- ***Best Guess (Mean) Scenario.*** We calculate the cost savings for this scenario by adding the savings for each regulatory possibility in each jurisdiction, multiplied by a weighting factor equal to the likelihood that the regulation would have been imposed.

- ***Low Impact Scenario.*** We calculate the cost savings for this scenario by reducing the best guess estimate by 10 percent.

- ***High Impact Scenario.*** We calculate the cost savings for this scenario by increasing the best guess estimate by 10 percent.

Table 5.5
Total Cost Savings to the Canadian Pulp and Paper Industry Due to Knowledge of AOX ($million 1993)

Scenario	Calculation	Total Hypothetical Cost Savings
Best Guess	20 (Prairie) + 597 (Ontario) + 526 (Québec)+ 31 (Atlantic)	1,174
Low Impact	1,174 (Best Guess) x 0.9	1,057
High Impact	1,174 (Best Guess) x 1.1	1,291

5.1.6 Summary

NWRI research contributed to a significant degree (between 60 and 90 percent) to knowledge that AOX is not a suitable parameter to judge the toxicity of effluents. This meant that some provinces and the Federal government did not implement as stringent AOX regulations as they otherwise would have.

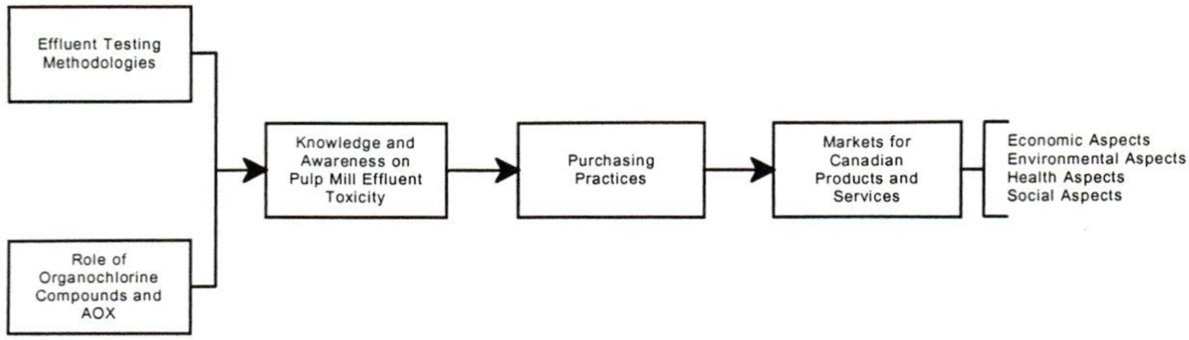
With respect to the environmental effects of the less stringent regulations, Environment Canada's view is that it is not aware of any information indicating that net environmental benefits were foregone as a result of not regulating AOX.

With respect to the capital and production costs of the less stringent regulations, given certain assumptions about the technology and the avoided regulations, cost savings would amount to (in 1993 dollars):

- Low Impact Scenario: $1.06 billion
- Best Guess Scenario: $1.17 billion
- High Impact Scenario: $1.29 billion.

5.2 THREAD 2: AOX-RELATED IMPACTS ON MARKETS FOR CANADIAN PULP AND PAPER PRODUCTS

Figure 5.2 -- Thread 2



Thread 2 is illustrated in Figure 5.2. It postulates that NWRI research and information efforts provided credible arguments that pulp bleached with chlorine dioxide was as environmentally sound as chlorine-free pulp. This led consumers of pulp and paper products (particularly in Europe) to keep buying pulp bleached with chlorine dioxide generally, and Canadian products in particular. The markets that were retained translated to overall economic and social benefits.

The linkages are:

- Impact of NWRI research outputs on knowledge and awareness of AOX and the toxicity of organochlorines
- Impact of knowledge and awareness of AOX and the toxicity of organochlorines on the purchasing practices of consumers
- Impact of the purchasing practices of consumers on markets for Canadian pulp and paper products.

These linkages are considered, in turn, in the following subsections.

5.2.1 Immediate and Intermediate Impacts: Impact of NWRI Research Outputs on Knowledge and Awareness of AOX and the Toxicity of Organochlorines

The contribution of NWRI to the knowledge and awareness of the effects of organochlorines and the suitability of AOX was discussed in Section 5.1.1. While the main targets of this knowledge were Canadian Federal regulators, it also informed foreign regulators and consumers. At the invitation of Canadian Trade representatives, NWRI helped disseminate the knowledge and provided a credible non-industry voice to counter the proponents of chlorine-free bleaching products.

The attribution of the impact to NWRI was previously determined in Section 5.1.1:

Contribution of NWRI to the awareness that AOX is not a suitable parameter to judge the toxicity of effluents and that substances other than organochlorines are responsible for observed sub-lethal effects:

- Low impact scenario: 60%
- Best guess scenario: 75%
- High impact scenario: 90%.

5.2.2 Immediate and Intermediate Impacts: Impact of Knowledge and Awareness of AOX and the Toxicity of Organochlorines on the Purchasing Practices of Consumers

Based on the interviews, it is clear that the key markets where changes in purchasing practices would have occurred based on AOX concerns were located in Europe (particularly the Germanic and Scandinavian countries) and were concerned with wood pulp.

- In 1990 Greenpeace circulated a flyer to over 8 million households in Germany implicating chlorine as an extremely damaging element of pulp and paper effluent. The flyer was done in the form of a parody of *der Spiegle*. The tactic succeeded in putting tremendous pressure on German magazine and newspaper publishers to take a "life-cycle" view of their products. The pressure spilled over to paper suppliers in German speaking countries, then Italy, then the rest of Europe.
- European trade restrictions and requirements for recycled content prevented significant quantities of paper and newsprint imports, thereby making it difficult for foreign producers to dilute the AOX effluent "content" by producing integrated products for sale in Europe.
- Unlike in other areas, such as the United States, the European pulp and paper industry was not united in denouncing AOX restrictions as premature in the early 1990s. In fact, integrated sulphite mills in Germany, who could easily convert to TCF, saw the introduction of AOX restrictions as a competitive advantage. Moreover, mills in Nordic countries were actively marketing their TCF products as environmentally superior to ECF pulps.[32]

These changes could also have affected paper products; however, paper producers generally succeeded in deflecting concerns by pointing to the extremely low levels of AOX-associated content contained in their products as a result of the blending in of TCF, unbleached pulp and recycled paper. We assume that this practice would have been used to deflect any threat to those markets (which coincidentally are of limited concern to Canadian producers who sell few paper products in Europe).

[32] John Carey, NWRI, Richard Cockram, NLK Consultants, UK, McCubbin Consultants.

In the analysis we consider only the effects on European markets for bleached wood pulp. This is a conservative assumption but also a reasonable one considering the evidence of market vulnerability.

In 1990, forecasts for European pulp consumption hypothesized a TCF market share as high as 100 percent within five years.[33] By 1994 it was apparent that these extreme predictions would not prove to be correct, because consumers continued to use ECF in large amounts in all regions of Europe.

Although many factors, particularly economic factors, contributed to maintaining demand for ECF pulp, industrial consumers of pulp and pulp producers did not have an independent expert source to defend their use of ECF pulps from an environmental point of view.[34] In 1994, NWRI, in its efforts to support the regulatory role of Environment Canada, coincidentally met the needs of the industry.

In the absence of NWRI's research which proposed that ECF pulp was not environmentally inferior to TCF pulp, would the producers and industrial consumers in Europe been able justify to the end consumer, environmental groups and various governments that ECF pulp was preferable? Canadian industry experts generally agree that the answer is no; without the science to support ECF as environmentally sound, demand for TCF would have in part replaced ECF from 1993 forward.[35] This shift would have been a reflection of consumer and even regulatory preferences for pulps with no organochlorines.

We begin by focusing our attention on the market in Germany.

The Base Case – Germany

In order to appreciate the change in purchasing practices that would have occurred in the absence of the research, we consider, first, the shift in purchasing practices that did occur.

It would be easy to statistically calculate this shift if there was data on the consumption of conventional, ECF and TCF market bleached pulps by country, or region. Unfortunately, no such data exists -- there is production data by type of bleached pulp by country for market and integrated pulps combined, but no consumption data.

To circumvent this problem we constructed a market model that back-tracked from an industry

[33] Richard Cockram, NLK Consultants, UK.

[34] Brian McClay, CPPA.

[35] This argument was repeated by officials of Environment Canada, the CPPA, AET and NLK Consultants.

supposition that market share for TCF pulps is currently (1996) about 30 percent in Germany.[36] By assuming that the growth of TCF pulp consumption parallelled the growth of TCF pulp production, and that the German share of world TCF consumption remained constant, we used annual world TCF production levels to construct a time series for market pulp consumption by bleach type back to 1993 (the year before the effects of NWRI's work would have had an effect). The result is a starting share of 17 percent for TCF pulp in 1993. This share grew to 30 percent by 1996 (despite the knowledge provided by NWRI).

Details of the calculations employed are provided in Appendix H.

Market Share Scenarios – Germany

Three plausible alternative scenarios for what would have happened to European purchasing practices, without the influence of the research results, have been developed for analysis. These scenarios are based on discussions with industry and government officials at the CPPA, AET, NLK Consultants and Environment Canada. The scenarios have the following characteristics:

- In all three scenarios it is consumer preference that is driving the shift from ECF and conventional pulps to TCF pulp. Government product regulations might have been a factor but we assume that they would not have been a significant driver in the near term. The scenarios also assume that consumer preference would have been sufficient to overcome any price or quality premium that might have had to be paid for TCF pulp.

- Secondly, the scenarios are based on a growth in the market share of TCF (from the initial 17%) and a corresponding fall in the share of other bleached pulps. Because paper manufacturers use bleached pulp, non-bleached pulp and recycled fibres in relatively fixed proportions, there were limited short-run opportunities to substitute mechanical (non-bleached) pulps for chemical pulps in Europe.

- Thirdly, each scenario posits a new current (1996) market share for TCF pulp based on anti-AOX consumer preferences. The size of the market share (50%) for the best guess scenario was chosen on the basis of estimates provided by industry experts and was further discounted to ensure that the result was conservative. The additional scenarios: 40% (low impact scenario), and 60% (high impact scenario) were chosen to reflect a reasonable range of uncertainty and to reflect the factors discussed below.

- Finally, the TCF share of the market was assumed to grow linearly from 1993 to 1996.

The resulting market shares are presented in Table 5.6.

[36] Richard Cockram, NLK Consultants UK.

Table 5.6
Summary of Potential Market Shares for Bleached Pulp in Europe

Scenario	Products	1993	1994	1995	1996
Base Case	TCF	17%	24%	27%	30%
	ECF and Conventional	83%	76%	73%	70%
Low Impact	TCF	17%	25%	32%	40%
	ECF and Conventional	83%	75%	68%	60%
Best Guess	TCF	17%	31%	45%	70%
	ECF and Conventional	83%	69%	55%	30%
High Impact	TCF	17%	31%	46%	60%
	ECF and Conventional	83%	69%	54%	40%

Comparing the scenarios to the base case, we obtained a percent decline in ECF+Conventional pulp consumption for each period. The result is shown in Table 5.7.

Table 5.7
Decline in German Consumption of ECF+Conventional Bleached Pulp due to Hypothetical Changes in Purchasing Practices

Scenario	Hypothetical Decline in ECF+Conventional Pulp Consumption (Compared to Actual Consumption)			
	1993	1994	1995	1996
Low Impact	0%	0.5%	7.1%	14.3%
Best Guess	0%	4.9%	16.2%	28.6%
High Impact	0%	9.3%	25.3%	42.9%

Decline in European Consumption of ECF Conventional Bleached Pulp

To adapt the German experience to other European markets, we assume that consumers in other Germanic countries and Scandinavia would have reacted in tandem with those of Germany while the rest of Europe would have followed with a one year delay.

Results are as follows:

Table 5.8
Decline in European Consumption of ECF+Conventional Bleached Pulp due to Hypothetical Changes in Purchasing Practices[37]

Scenario	Market	% Decline Compared to Actual Consumption			
		1993	1994	1995	1996
Low Impact	Germany	0	0.5	7.1	14.3
	Germanic and Scandinavian	0	0.5	7.1	14.3
	Rest of Europe	0	0	0.5	7.1
Best Guess	Germany	0	4.9	16.2	28.6
	Germanic and Scandinavian	0	4.9	16.2	28.6
	Rest of Europe	0	0	4.9	16.2
High Impact	Germany	0	9.3	25.3	42.9
	Germanic and Scandinavian	0	9.3	25.3	42.9
	Rest of Europe	0	0	9.3	25.3

The three scenarios are described in qualitative terms as follows:

Low Impact Scenario (40% Market Share in 1996)

This scenario sees a definite preference for TCF paper products but because TCF production cannot meet all the increased demand, ECF and conventional producers gain some breathing room. This happens because expansion of TCF production capacity in Scandinavian countries to meet the growing demand is somewhat slow. As a result, demand outstrips supply and TCF becomes relatively more and more expensive for paper producers. Capacity limitations set the constraint on TCF pulp growth. Pulp producers (including Canadian producers) take advantage of the TCF capacity constraint in Europe to continue to sell some of the existing ECF capacity on European markets.

[37] Given the lack of consumption data after 1996, no attempt is made to estimate the % decline after that year. Instead, we assume that the market losses would have remained constant after 1996. This is a conservative assumption since it means that the % decline in the rest of Europe never attains German levels.

Best Guess Scenario (50% Market Share in 1996)

This scenario is essentially the same as the first except that it supposes that the capacity constraint in TCF production is somewhat less severe. In effect, high demand and the resulting price premiums would have pulled other European producers into the TCF market.

High Impact Scenario (60% Market Share in 1996)

This is the worst case for ECF producers. It proceeds along the same lines as the other scenarios except that efforts of ECF producers to join the TCF market in Europe would not have been very successful. As a result, the initial price premium would have made it extremely worthwhile for European producers to quickly add TCF capacity. All this activity would have led to improvements in quality and production practices that would have lowered the premium that had to be paid for TCF pulp.

5.2.3 Ultimate Impacts: Impact of the Purchasing Practices of Consumers on Markets for Canadian Pulp and Paper Products

As mentioned earlier, NWRI played a role in protecting markets for Canadian products. Quantifying this role involves a three-step process (described in more detail in Appendix G):

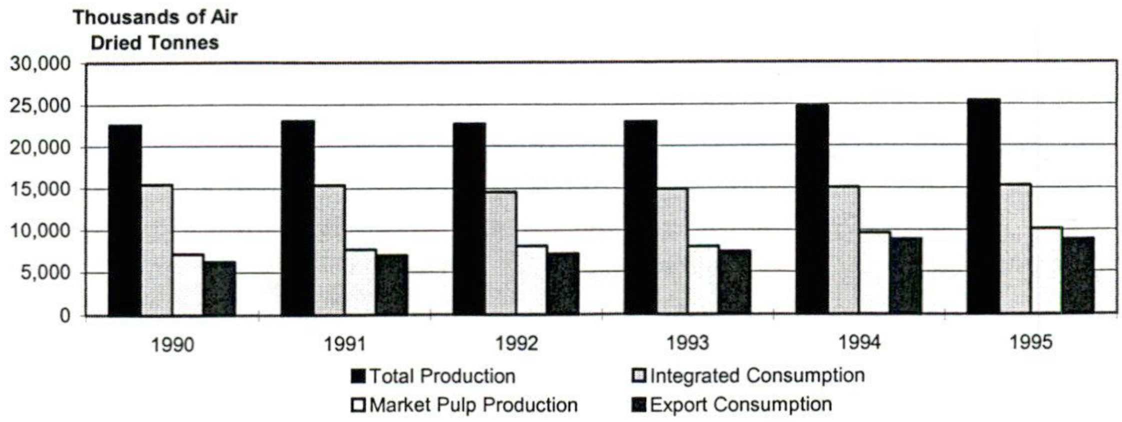
- ***Step 1*** -- Determine the nature and size of the market for Canadian exports that were at risk
- ***Step 2*** --Assess the ability of Canadian industry to respond to changes in purchasing practices
- ***Step 3*** -- Determine how the market share for Canadian products would have changed, and the value of this change

Step 1 -- Nature and Size of the Market at Risk

Canadian pulp production was over 25 million tonnes in 1995 (see Figure 5.3). More than half of this production (15 million tonnes) was not sold on the open market but was consumed by integrated mills, that is companies that produce pulp and consume it themselves (usually at the same mill) in the production of paper and paper board products.

The remaining 10 million tonnes produced in 1995 was sold as market pulp in Canada and abroad. The foreign markets were by far the most important for Canadian market pulp, with exports accounting for 88 percent of market pulp production in 1995 (99 percent if shipments to U.S. affiliates of Canadian firms are included) and a market value of $10.6 billion. Export markets represented nearly 90 percent of all Canadian market pulp sales by volume between 1990 and 1996.

Figure 5.3 -- Canadian Wood Pulp Production and Market of Consumption



In order to establish the portion of Canadian exports at risk, we need to distinguish between bleached and unbleached pulp exports. Unfortunately Statistics Canada's tracking of exports is based on the Harmonized System of Commodity Classification (HS), which does not account for the bleached vs. unbleached characteristics of the exports. It is, therefore, necessary to reclassify Canadian exports by the type of HS pulp commodities that involve bleaching and those that do not:

Non-Bleached

- Mechanical Wood Pulp
- Chemical Wood Pulp Dissolving Grades
- Chemical (soda or sulphate or sulphite) non-bleached Wood Pulp, non-bleached
- Semi-chemical Wood Pulp

Bleached

- Chemical (soda or sulphate or sulphite) Wood Pulp, semi-bleached or bleached, not elsewhere specified

Based on this reclassification, we can isolate the portion of Canada's exports (i.e, bleached pulp) that would have been at risk of being affected by AOX concerns (see Figures 5.4 and 5.5).

Figure 5.4 – Quantity of Canadian Exports of Bleached and Unbleached Pulp

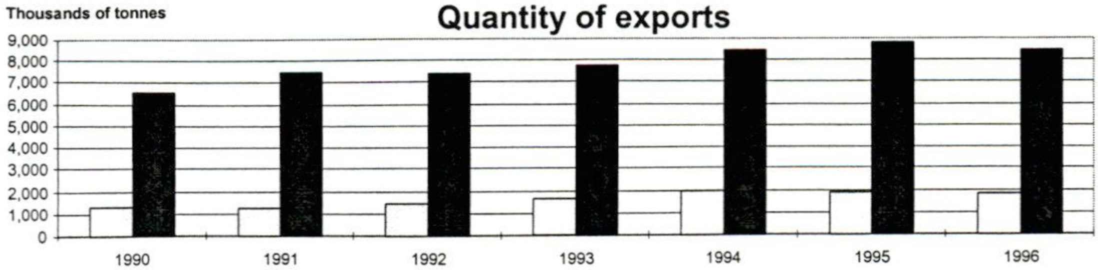
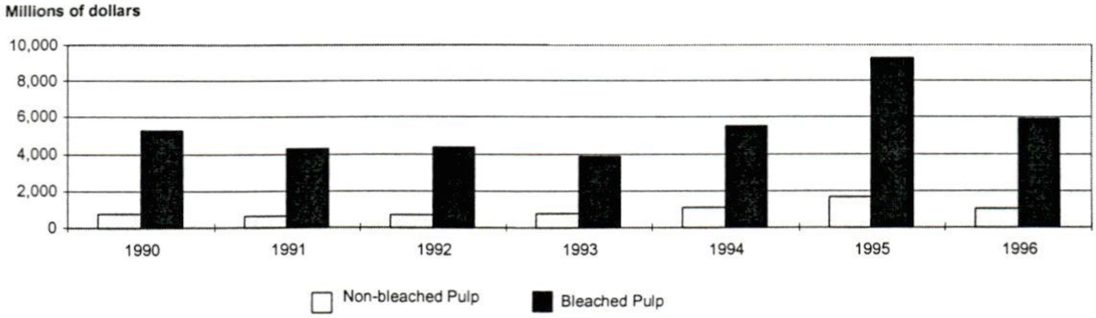


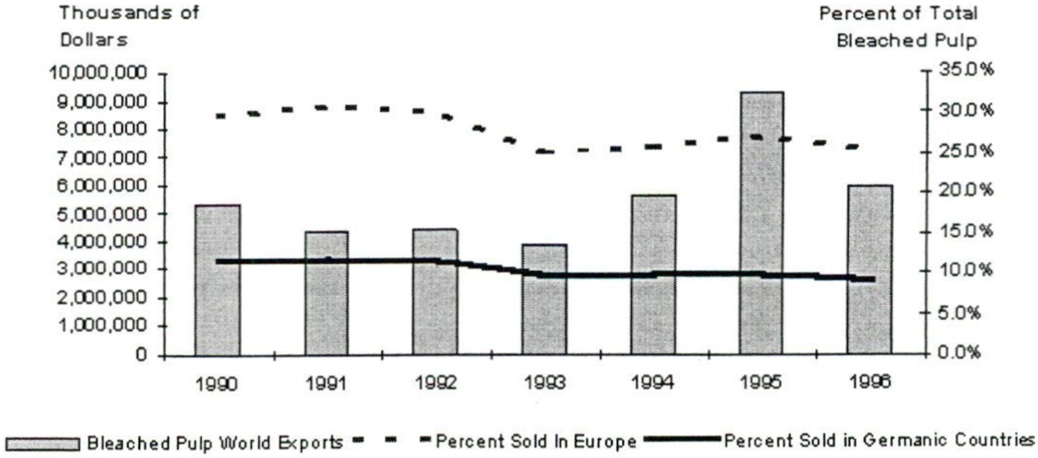
Figure 5.5 -- Value of Canadian Exports of Bleached and Unbleached Pulp



Concerns about AOX effluents were more important in some markets than others. In particular, European markets and within Europe, the Germanic countries, had the strongest anti-AOX pressures.

At stake in the European markets was about a quarter to one third of Canada's bleached market pulp production sales (see Figure 5.6). On the basis of total exports, the Germanic countries of Austria, Switzerland and Germany alone represent about 10 percent of bleached export sales.

Figure 5.6 -- Canadian Bleached Pulp Production and Percent Sold in Europe



The total value of Canadian markets for bleached pulp in Europe have more or less followed the world trend with a peak in 1995, reflecting strong demand for pulp and consequent high prices. Also in accordance with world trends, European markets fell sharply with the collapse of pulp prices in 1996 (see Table 5.9).

Table 5.9
Value of Canadian Exports of Bleached Market Pulp ($million) – Base Case

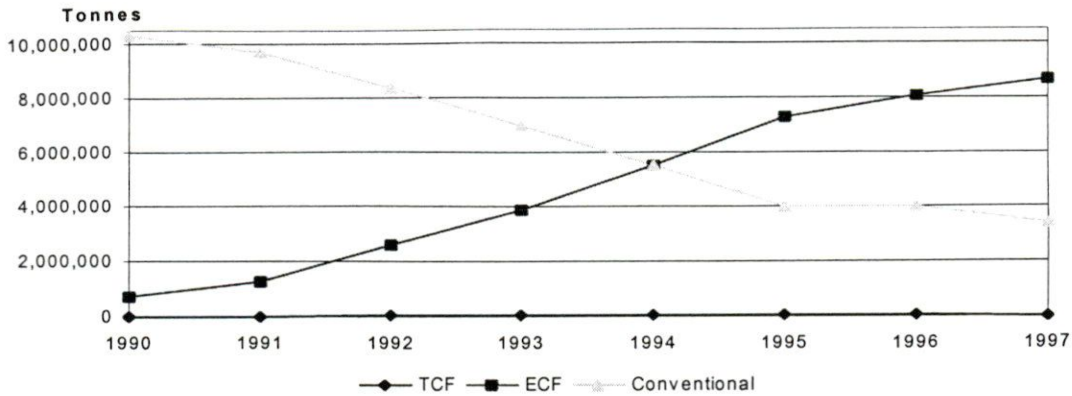
Market	1990	1991	1992	1993	1994	1995	1996
Germanic	614	501	503	372	547	899	533
Scandinavia	11	5	6	9	12	37	2
Rest of Europe	965	825	796	592	875	1,575	966
Total Europe	1,591	1,331	1,306	973	1,435	2,511	1,501
Rest of World	3,761	2,980	3,063	2,909	4,149	6,750	4,414
Total	5,352	4,312	4,369	3,883	5,584	9,261	5,915

Source: Statistics Canada, Exports by Commodity, 1990 to 1996.

Step 2: Ability of Canadian Exporters to Respond to Changes in Purchasing Practices

In Canada there has been substantial substitution of ECF pulp for conventional pulp (see Figure 5.7). However, to date, only one mill in Canada has produced TCF bleached pulp.[38] With the growing share of ECF pulp, AOX levels in Canadian pulp have fallen drastically.[39] However, virtually all Canadian sales to Europe of bleached pulp generate some AOX effluent.

Figure 5.7 --Total Production of Canadian Bleached Pulp by Bleaching Process



Although it is possible that Canadian producers could have switched to producing TCF pulp, this analysis assumes that such a switch would not have occurred for the following reasons:

- The relatively older capital stock of Canadian mills, which would have made it more expensive to make TCF than in the case of the more modern European mills (many of which already had oxygen delignification - a key building block).
- Canadian TCF pulps would not command the quality competitive advantage enjoyed by Canadian ECF pulps (particularly BC products).
- The fact that no switch has occurred despite an estimated increase in TCF market share in Germanic countries from 17% to 30%.

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[38]The Howe Sound mill in British Columbia produced 40,000 to 50,000 tonnes per year of TCF on an experimental basis.

[39]The CPPA estimates that average AOX in Canadian mill effluents fell by 81 percent between 1981 (4.8 kg per tonne of pulp), and 1995 (0.9 kg per tonne) . Recent mill openings and upgrades indicate that the level is still dropping.

Step 3: Expected Changes in the Size of the Canadian Market and Value of Potentially Lost Exports

To calculate the expected changes in Canadian market share, we use the three scenarios of Table 5.8. In each case, we can apply the change in purchasing practices to Canadian exports by assuming that:

- In accordance with the arguments made in Step 2 above, the Canadian share of the market for TCF remains at 0.
- The Canadian share of the market for ECF+conventional remains unchanged (and hence the total share of the market for Canadian ECF+conventional declines at the same rate as the decline of the total ECF+conventional market share).

These assumptions allow us to calculate the total loss of markets for Canadian bleached pulp in each of the scenarios using the decline in market size (Table 5.8) and the value of the market (Table 5.9).

The percentage reductions in Table 5.8 refer to the quantity of pulp sold. However, we can calculate the value of the lost market by assuming that the loss of revenue would have been directly proportional to the reduction in quantity of pulp sold. In other words, the percentages in Table 5.8 can be applied to the Base Case value of Canadian exports as presented in Table 5.9, to arrive at the value of lost exports in each year.

To complete the analysis, these annual figures need to be adjusted to 1993 dollars. This involved three calculations:

- First we must recognize that trade continued in 1997 and will do so on into the future. Unfortunately, formulating alternate futures is even more difficult and speculative than hypothesizing alternate scenarios for the past. Technology developments, new scientific revelations, further changes in consumer tastes, shifts in relative strengths in economies (or simply exchange rates), even disasters can serve to exacerbate or mitigate the potential losses. Traditionally, analysts deal with this problem by either ignoring the future or proposing a revenue stream and then appropriately discounting it to reflect the uncertainty. In this analysis the estimated level of export losses in 1996 was carried forward for twenty years but was heavily discounted at 30 percent per year. In effect this means that a dollar of export losses in 2002 was counted as four cents in the final tally. The scenarios also assume that market losses remain constant after 1996 (meaning that the market decline in the rest of Europe remains at Germany's 1995 level). This is a conservative assumption that also makes it easier to deal with the lack of consumption data after 1996.

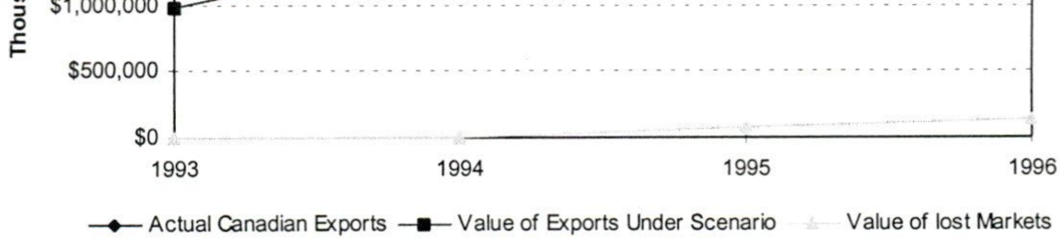
The second adjustment is also about discounting to reflect uncertainty. However, in this case, we are concerned with the contingent export losses in the past (between 1993 and 1996). Discounting these losses reflects the uncertainty that is generated by supposing changes in past operating conditions for businesses. Threatened with substantial market contractions, Canadian firms might have innovated to minimize their potential losses. They could have, for example, developed new markets, or developed technologies, at a cost, to help keep their markets in Europe secure. Accordingly, the streams of lost export sales between 1993 and 1996 were also discounted, but at a less severe rate of 10 percent (10 percent is used instead of 15 percent as in Section 5.1.5, because the uncertainty here is considered less pronounced than in the case of the operating cost calculations).

Results are as follows:

Low Impact Scenario

Under this scenario, market losses in the Germanic and Scandinavian region would have reached $76 million by 1996, for a cumulative loss of $145 million in export sales between 1993 and 1996. Consumers and producers in the rest of Europe would respond in a similar fashion a year later. This would have led to a further cumulative loss of $77 million in export sales by 1996. Combined export losses throughout Europe would have been $222 million (undiscounted, to 1996).

Figure 5.8 -- Low Impact Scenario: Canadian Bleached Pulp Markets in Europe Actual Exports Versus Projected Exports



With the applicable discounts, the results are shown in Table 5.10.

Table 5.10
Discounted Present Value of Export Losses Under Low Impact Scenario ($million 1993)

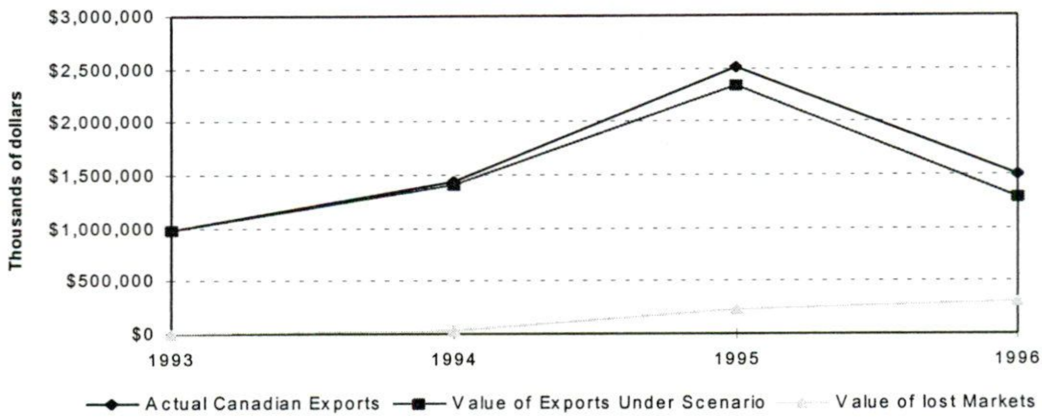
Market	1993	1994	1995	1996	Annually from 1997 to 2012	Total
Germanic and Scandinavia	0	3	66	76		
Rest of Europe	0	0	8	68		
All Europe	0	3	74	144	144	
Total Discounted Net Present Value	0	2	56	99	157	323

The final impact of the loss of export market due to anti-AOX sentiments under this scenario is $323 million.

Best Guess Scenario

Under this scenario, market losses in the Germanic and Scandinavian region would have reached $153 million by 1996, for a cumulative loss of $332 million in export sales between 1993 and 1996. Consumers and producers in the rest of Europe would respond in a similar fashion a year later. This would have led to a further cumulative loss of $234 million in export sales by 1996. Combined export losses throughout Europe would have been $566 million.

Figure 5.9 -- Best Guess Scenario: Canadian Bleached Pulp Markets in Europe
Actual Exports Versus Projected Exports



With the applicable discounts, the results are shown in Table 5.11

Table 5.11
Discounted Present Value of Export Losses Under Best Guess Scenario ($million 1993)

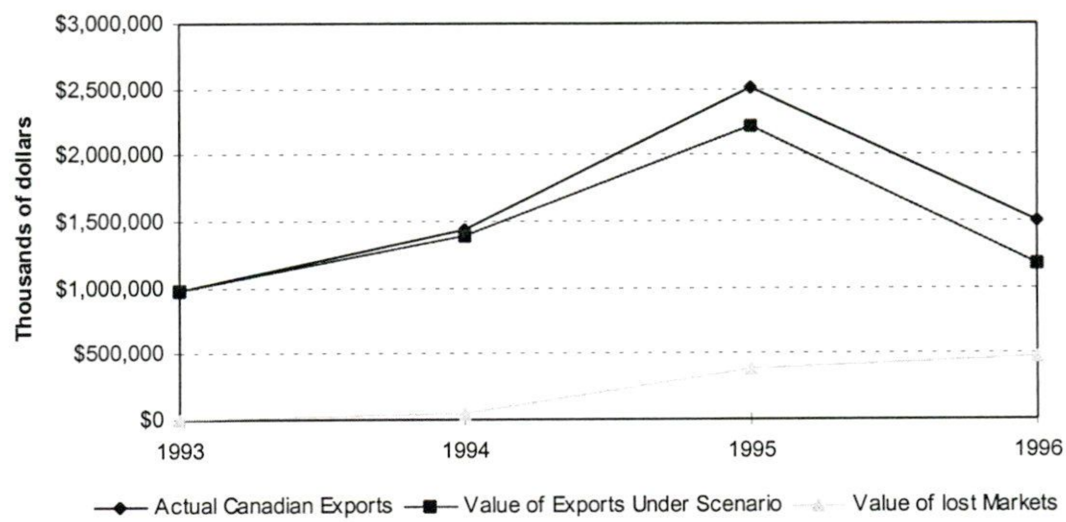
Market	1993	1994	1995	1996	Annually from 1997 to 2012	Total
Germanic and Scandinavia	0	28	152	153		
Rest of Europe	0	0	78	156		
All Europe	0	28	230	309	309	
Total Discounted Net Present Value	0	23	172	211	356	762

The final impact of the loss of export market due to anti-AOX sentiments under this scenario is $762 million.

High Impact Scenario

Under this scenario, market losses in the Germanic and Scandinavian region would have reached $229 million by 1996, for a cumulative loss of $518 million in export sales between 1993 and 1996. Consumers and producers in the rest of Europe would respond in a similar fashion a year later. This would have led to a further cumulative loss of $392 million in export sales by 1996. Combined export losses throughout Europe would have been $910 million.

Figure 5.10 -- High Impact Scenario: Canadian Bleached Pulp Markets in Germanic & Scandinavian Countries - Actual Exports Versus Projected Exports



With the applicable discounts, the results are shown in Table 5.12

Table 5.12
Discounted Present Value of Export Losses Under High Impact Scenario ($million 1993)

Market	1993	1994	1995	1996	Annually from 1997 to 2012	Total
Germanic and Scandinavia	0	52	237	229		
Rest of Europe	0	0	147	245		
All Europe	0	52	384	474	474	
Total Discounted Net Present Value	0	43	289	324	542	1198

The final impact of the loss of export market due to anti-AOX sentiments under this scenario is $1.2 billion.

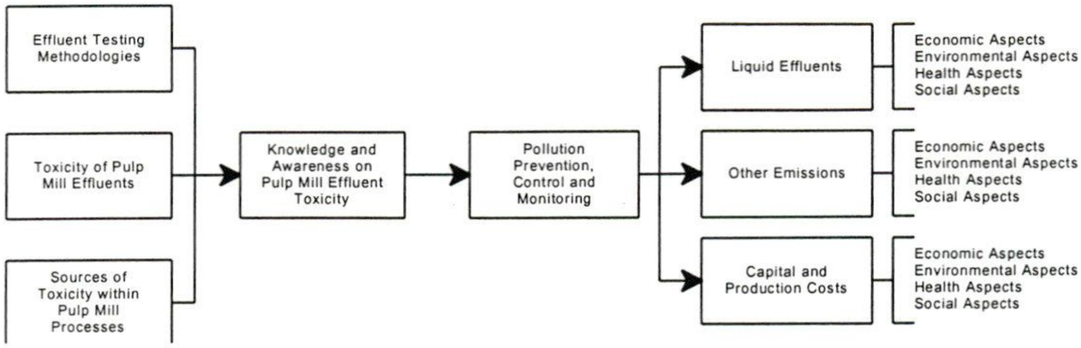
5.2.4 Summary

NWRI research contributed to a significant degree (between 60 and 90 percent) to knowledge and awareness that AOX is not a suitable parameter to judge the toxicity of effluents. Our analysis indicates that, given certain assumptions about the nature of changes to European purchasing practices and specifically, the 1996 market share for TCF in Germanic and Scandinavian countries, the research results protected markets valued at (in 1993 dollars):

- Low Impact Scenario (40% share for TCF): $323 million
- Best Guess Scenario (50% share for TCF): $762 million
- High Impact Scenario (60% share for TCF): $1.2 billion.

5.3 THREAD 3 -- IMPACTS ON LIQUID EFFLUENTS AND OTHER EMISSIONS (AND CAPITAL AND PRODUCTION COSTS) FROM CHANGES TO PULP MILL PROCESSES

Figure 5.11 -- Thread 3



Thread 3 is illustrated in Figure 5.11. It postulates that NWRI research identified a series of pulp mill process components and practices that are at least partially responsible for observed sub-lethal toxic effects in fish. As mills implement measures to mitigate or eliminate these sources of toxicity (most likely through voluntary measures aimed at moving towards a minimum impact mill), the characteristic of liquid effluents will improve. Improved effluents will have beneficial consequences for ambient water and sediment quality which will eliminate (or at least reduce) the observed sub-lethal toxic effects. It may also reduce the risk of other unknown environmental effects and, at the same time, protect human health. The measures may also involve changes in other emissions and in capital and operating costs.

The linkages are:

- Impact of NWRI research outputs on knowledge and awareness of sources of toxicity within mill processes
- Impact of knowledge and awareness of sources of toxicity within mill processes on pollution prevention and control measures
- Impact of pollution prevention and control measures on liquid effluents
- Impact of pollution prevention and control measures on other emissions
- Impact of pollution prevention and control measures on capital and production costs.

These linkages are considered, in turn in the following sub-sections.

5.3.1 Immediate and Intermediate Impacts: Impact of NWRI Research Outputs on Knowledge and Awareness of Sources of Toxicity within Mill Processes

The items of knowledge at issue are:

Knowledge that Canadian pulp mill effluent (whether bleached with chlorine or not) causes sub-lethal toxic effects

Knowledge of test methods to evaluate the toxicity of effluents

Knowledge that the potential sources of toxicity within mill processes could include:

- *black or cooking liquors from digesters;*
- *digester condensates;*
- *breakdown of resin acids in secondary treatment;*
- *use of certain additives (e.g., defoamers).*

The first conclusion emerged from NWRI research undertaken in the period 1988-89, at Jackfish Bay and in the St. Maurice River. In the mid 1980s, Swedish researchers had reported a variety of sub-lethal effects on fish from bleached kraft mills in the Baltic Sea. However, the applicability of these results to North America was questioned by a panel of scientists convened by Proctor and Gamble and by studies undertaken by the U.S. National Council of the Paper Industry for Air and Stream Improvement (NCASI). The work by NWRI indicated that the responses of fish to effluent from bleached kraft mills in Canada were analogous to those observed in Sweden.

Evidence for the attribution of this result to NWRI can be found in the publications presented at the Saltsjobaden Conference in 1991 (cited in Section 5.1.1) and in the historical account provided by Van Nijnatten and Leiss.[40] Further evidence comes from the results of interviews which included the following comments:

- NWRI was 100% responsible for determining that sublethal effects similar to those found in the Baltic also occurred in North America.
- In 1990-91 when NWRI started the two mill and ten mill studies, the only North American studies showed no sub-lethal effects in North America.
- NWRI was one of the few groups whose work led to the conclusion that the sublethal effects observed in fish in Scandinavia were present in North America as well.
- The discovery of sublethal toxic effects in fish in receiving waters of North American pulp mills can be attributed to NWRI which did field studies and to Paprican and NCASI which did respectively laboratory and artificial stream studies.

[40] VanNijnatten, D. L., Leiss, W., and Hodson, P.V. (Draft 1997). *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada*. Kingston, Ontario.

- NWRI work in the late 1980s found the same sublethal effects as the Swedish studies. Other North American studies following release of the Swedish findings concluded that the Swedish effects could not be reproduced in North America.

The knowledge that there was a problem led NWRI to develop testing methodologies and investigate the sources of the toxicity.

Contributions to testing methodologies included development of in vivo and in vitro tests (including an assay describing steroid production), and development of bioassay-driven methods for isolating toxic components of complex mixtures. The contribution of NWRI to these methods is documented in Munkittrick, et. al. (draft, 1996).[41] Further evidence of NWRI's contributions is provided by citations related to methods in several of the publications presented at the Second International Conference on Environmental Fate and Effects of Pulp and Paper Mill Effluents, held in Vancouver in 1994.[42]

In addition, interviews collected the following comments:

- The development and miniaturization of test methods was a very important outcome. It was terrific work.

- Development of the protocols for environmental effects monitoring and the interpretation protocols done by NWRI was great work. The standardization of test methods was very important. There are discussions now in Sweden about using these tests.

Knowledge of the problem's existence and new test methods contributed to the most relevant research result (for measuring tangible impacts), which was the identification of a series of potential sources of toxicity.

According to NWRI, they were mainly responsible for identifying black or cooking liquors from digesters as a source of toxicity, contributed significantly to the identification of the breakdown of resin acids in secondary treatment as a source and contributed somewhat to the identification of digester condensates and additives as sources.

NWRI's contribution on the subject of black and cooking liquor losses is documented in Munkittrick et. al. (1996)[43] and in Axegard et. al. (Draft, 1997).[44] Further acknowledgment of

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[41]Munkittrick, K.R., McMaster, M.E., McCarthy, L.H., Servos, M.R. and Van Der Kraak, G.J. (Draft, 1996). *Determination of the Threshold Exposure Levels for Biological Effects of Pulp Mill Effluents*. Burlington and Guelph, Ontario.

[42]Servos, M.R., Munkittrick, K.R., Carey, J.H. and Van Der Kraak, G.J. *Environmental Fate and Effects of Pulp and Paper Mill Effluents*. 1996. St. Lucie Press, Delray Beach, Florida.

[43]Munkittrick, K.R., Servos, M.R., Carey, J.H. and Van Der Kraak, G.J. 1996. *Environmental Impacts of Pulp and*

this contribution, as well as contributions to knowledge of the role of digester condensates, breakdown of resin acids, and certain additives, was obtained through the interviews:

- NWRI research on non-bleached sources of effluent toxicity contributed to U.S. EPA emphasis in regulation on pulping liquor management.

- The NWRI research strengthened arguments for closing up effluents and closed loop processes in mills. The research which identified pre-bleach causes of sub-lethal toxicity helped to define the characteristics of a minimum impact mill and highlighted the need to reduce the emissions of the complex mixture of organics.

- NWRI made a contribution to developing an appreciation of the importance of effluent from unbleached stages of processing and contributed to the conclusion that secondary treatment was necessary. The Swedes and Paprican also contributed.

Based on the available information, attribution estimates have been prepared for each of the potential sources of toxicity identified. These estimates incorporate work on the specific sources as well as the contribution to methods and the original result that confirmed that the effluent was responsible for toxic effects. The estimates are summarized in Table 5.13.

Paper Wastewater: Evidence for A Reduction in Environmental Effects at North American Pulp Mills Since 1992. Burlington and Guelph, Ontario.

[44] Axegard, P., Carey, J., Folke, J., Gleadow, P., Gullichsen, J., Pryke, D.C., Reeve, D. W., and Swan B. (Draft, 1997). *Minimum-Impact Mills: Issues and Challenges.* Sweden, Canada, Denmark, Finland.

Table 5.13
Estimated Attribution of R&D Results Concerning Sources of Toxicity within Pulp and Paper Mills

Source	Scenario	Attribution (%)
Black or cooking liquors	Low impact	60
	Best guess	75
	High impact	90
Digester condensates	Low impact	10
	Best guess	20
	High impact	30
Breakdown of resin acids in secondary treatment	Low impact	40
	Best guess	50
	High impact	60
Additives	Low impact	10
	Best guess	20
	High impact	30

5.3.2 Immediate and Intermediate Impacts: Impact of Knowledge and Awareness of Sources of Toxicity within Mill Processes on Pollution Prevention and Control Measures

Although knowledge of sources of toxicity is relatively recent, some impacts are beginning to emerge. For the most part, mills appear to be willing to implement changes on a voluntary basis rather that be coerced by regulation. This is manifesting itself in the adoption by the industry of the vision of the "minimum impact mill". Although this vision is undoubtedly meant to compete with the more costly and perhaps unattainable "zero effluent mill", it nevertheless represents an apparent commitment on the part of the industry to rapidly implement measures to eliminate or reduce effluents that are shown to be toxic, notably from the pulping and recovery processes. As long as this commitment remains evident, there seems to be little likelihood of regulation (at least at the Federal level).

The measures associated with each of the sources of toxicity are identified in Table 5.14, along with the likely application of these measures within Canadian mills and the link to the research results.[45] The assumption is that mills will already have modernized by implementing measures such as oxygen delignification.

Table 5.14
Pollution Prevention and Control Measures Associated with Sources of Toxicity within Mill Processes

Source	Solution	Application	Linkage to Research Results
Black or cooking liquors	Spill Prevention and Diversion to Recovery System, brownstock washing	Approximately ½ of mills that employ cooking processes would benefit	Primary driver
Digester condensates	Steam Stripping (there is some question about the appropriateness of this solution)	Most mills	Might be used to reduce BOD and aid recovery of useful chemicals. The research results could accelerate progress or increase the incentive.
Breakdown of resin acids in secondary treatment	Reconfiguration of treatment system (exact solution not known)	All mills	Primary driver
Additives	Find Alternatives	All mills	Primary driver

Because of the recent nature of the research, the implementation of mitigation measures, with the possible exception of stream stripping, is still in the research or pilot testing stage:

- One mill has agreed to participate in a study of the effects of controls on cooking liquors.
- Ten mills are installing steam stripping equipment.
- Research on changes to treatment systems is only beginning.
- Alternative additives are being tested (a recent meeting sponsored by NCASI dealt with this issue).

5.3.3 Ultimate Impacts: Impact of Pollution Prevention and Control Measures on Liquid Effluents and Other Emissions

Although it is reasonably clear that the measures identified in Table 5.14 will have positive effects on effluent quality and quantity, describing these effects is difficult. A large number of

[45] Source: John Carey and Kelly Munkittrick (NWRI) and Neil McCubbin, N. McCubbin Consultants Inc. Foster, Québec.

chemicals are formed in the course of converting wood to bleached pulp (many of them originate in the wood). Given the complexity and diversity of modern kraft mills it is impossible to completely predict the chemical composition of effluents, nor is it possible to identify in detail the effect of particular process changes.

The best that can be done is to describe the effluents in qualitative terms:

- ***Black or Cooking Liquor***. May enter the effluent through spills or leaking seals in pumps. These liquors contain large amounts of wood extractives and pulping by-products, including hundreds of different compounds (e.g., acids, alcohols, aldehydes, ketones, sterols; aliphatic and aromatic compounds). Some compounds, such as setosterol (plant estrogen), are hormones that could be responsible for some of the observed reproductive effects in effluent.
- ***Digester Condensates***. Condensates contain many compounds similar to cooking liquors and are usually discharged to the treatment system. The effect of the treatment system is to remove many of the substances; however, some substances (including hormone analogs) persist and are discharged with the effluent.
- ***Resin Acids***. These can be transformed to oxidized forms or to aromatized structures such as retene in the treatment system.
- ***Additives***. Although some defoamers have been regulated as precursors to dioxin and furans, other defoamers and additives continue to be used. Some of these substances (e.g., nonyl phenol) have been shown to have reproductive effects.

Thus the effect of process changes would be to reduce the loadings of chemicals associated the corresponding waste streams described above.

With respect to other substances and other emissions, Environment Canada's view is analogous to its view concerning the environmental benefits of AOX reductions.

The Department is not aware of any information indicating that there would be any net environmental benefits (or costs) as a result of the implementation of the process changes described above, other than the benefits associated with the reduced loadings of chemicals associated with the corresponding waste streams.

Consequently, for the purposes of this study, only the impacts associated with those reduced loadings of chemicals are considered.

5.3.4 Ultimate Impacts: Impact of Pollution Prevention and Control Measures on Capital and Production Costs

The ability to identify costs depends on the nature of the proposed solution. In the case of spill control and brownstock washing, the costs are reasonably well know. In the case of finding alternatives for certain additives, the cost can be estimated based on similar past requirements. However, in the case of breakdown products from resin acids in the treatment process, the solution is as yet unknown and therefore it cannot be estimated.

Rough estimates of the associated costs for a typical mill are provided in Table 5.15[46]

Table 5.15
Rough Cost Estimates for Possible Toxicity Mitigation Measures in a Typical Mill

Source	Solution	Capital Cost	Operating Cost
Black or cooking liquors	Spill prevention and diversion to recovery system, brownstock washing	$4-6 million	Minimal (additional O&M will be offset by energy savings)
Digester condensates	Steam stripping	$1-2 million	$8-10 per tonne energy cost
Breakdown of resin acids in secondary treatment	Reconfiguration of treatment system (exact solution not known)	Unknown	
Additives	Find alternatives	Zero (there should be several substitutes available) -- the main cost will be the research to identify the appropriate choice.	

5.3.5 Summary

NWRI research contributed to varying degrees to confirming that effluent from pulp and paper mills in Canada was toxic, to the development of testing methods, and to the identification of sources of toxicity within mill processes, including:

- black or cooking liquors;
- digester condensates;
- breakdown of resin acids in secondary treatment; and
- additives (e.g., defoamers).

[46]Source: Neil McCubbin, McCubbin Consultants Inc.

These results will likely lead to the implementation of a variety of pollution prevention and control measures which will improve the quality and reduce the quantity of pulp and paper mill effluent by reducing the discharges of many substances which could have toxic effects. Implementation of these measures will entail costs ranging from zero for the replacement of additives to $4-6 million per mill to deal with black or cooking liquors.

6. EVALUATION OF IMPACTS

6.1 GLOBAL ATTRIBUTION AND SENSITIVITY ANALYSIS

In order to calculate the overall impact of NWRI's R&D, we need to combine our estimates of the proportional attribution of the research results to NWRI with the incremental impact of those results. This can be done on a quantitative basis for two of the three priority threads: Thread 1 -- AOX-related impacts on liquid effluents and other emissions, and capital and production costs avoided; and Thread 2 -- AOX-related impacts on markets for Canadian pulp and paper products. In the case of Thread 3 -- Impacts on liquid effluents and other emissions (and capital and production costs) from changes to pulp mill processes, the proportional attribution of the research results was estimated quantitatively, however, the impacts of those results could not be quantified.

The results include three scenarios for each thread:

- A low impact scenario that combines a low impact attribution of the R&D results to NWRI with a low incremental impact of those results.
- A best guess scenario that combines a best guess attribution of the R&D results to NWRI with a best guess calculation of the incremental impact of those results.
- A high impact scenario that combines a high impact attribution of the R&D results to NWRI with a high incremental impact of those results.

In the case of the low and high impact scenarios, we are combining two situations of low probability, resulting in an outcome that is even more unlikely. This should provide a reasonable degree of confidence that the actual impact is bounded by the low and high impact scenarios.

The results are summarized in Tables 6.1 to 6.3.

Table 6.1
Global Attribution of Impacts (Low Impact Scenario)

Thread	Attribution of R&D Results to NWRI	Incremental Impact of Research Results	Impacts Attributable to NWRI
Thread 1 -- AOX-related impacts on liquid effluents and other emissions, and capital and production costs avoided	60%	• $1.06 billion (Cost Savings) -- see Table 5.5No net environmental impacts	$640 million (Cost Savings)
Thread 2 -- AOX-related impacts on markets for Canadian pulp and paper products	60%	$323 million (Markets Preserved) -- see Table 5.10	$194 million (Markets Preserved)
Thread 3 -- Impacts on liquid effluents and other emissions (and capital and production costs) from changes to pulp mill processes	Black Liquors (60%)	• Higher effluent water quality and reduced quantity • Modest costs	
	Digester Condensates (10%)		
	Resin Acids in Secondary Treatment (40%)		
	Additives (10%)		

Table 6.2
Global Attribution of Impacts (Best Guess Scenario)

Thread	Attribution of R&D Results to NWRI	Incremental Impact of Research Results	Impacts Attributable to NWRI
Thread 1 -- AOX-related impacts on liquid effluents and other emissions, and capital and production costs avoided	75%	• $1.17 billion (Cost Savings) -- see Table 5.5No net environmental impacts	$878 million (Cost Savings)
Thread 2 -- AOX-related impacts on markets for Canadian pulp and paper products	75%	$762 million (Markets Preserved) -- see Table 5.11	$572 million (Markets Preserved)
Thread 3 -- Impacts on liquid effluents and other emissions (and capital and production costs) from changes to pulp mill processes	Black Liquors (75%)	• Higher effluent water quality and reduced quantity • Modest costs	
	Digester Condensates (20%)		
	Resin Acids in Secondary Treatment (50%)		
	Additives (20%)		

Table 6.3
Global Attribution of Impacts (High Impact Scenario)

Thread	Attribution of R&D Results to NWRI	Incremental Impact of Research Results	Impacts Attributable to NWRI
Thread 1 -- AOX-related impacts on liquid effluents and other emissions, and capital and production costs avoided	90%	• $1.29 billion (Cost Savings) -- see Table 5.5No net environmental impacts	$1.16 billion (Cost Savings)
Thread 2 -- AOX-related impacts on markets for Canadian pulp and paper products	90%	$1.20 billion (Markets Preserved) -- see Table 5.12	$1.08 million (Markets Preserved)
Thread 3 --Impacts on liquid effluents and other emissions (and capital and production costs) from changes to pulp mill processes	Black Liquors (90%)	• Higher effluent water quality and reduced quantity • Modest costs	
	Digester Condensates (30%)		
	Resin Acids in Secondary Treatment (60%)		
	Additives (30%)		

It should be noted that it is unlikely that the high impact scenarios for both Thread 1 and Thread 2 would occur at the same time. This is because the high impact scenario for costs would mean that Canadian producers would have begun to convert some capacity to TCF pulp production and would therefore have been in a position to compete (at least to some extent) with European TCF producers. This would make it less likely that the worst case loss of markets would have occurred.

Sensitivity Analysis

In reviewing the results of our analysis, it is important to note the sensitivity of the calculations to key inputs:

- Changes in our estimates of the proportional attribution of the research results have an obvious impact since they are applied directly to calculate the end result.

- The capital and production cost estimates are highly dependant on our speculative scenarios concerning regulations in the provinces in the absence of the research results. In particular, Ontario and Quebec account for a large share of the impacts ($1,123 million of the total of $1,174 million in the best guess scenario, or 96%). In contrast, the impact of Federal regulatory decisions is only $31 million in the same scenario (the effect being felt solely in the Atlantic provinces).
- Approximately one-half of the costs associated with Ontario and Québec regulations

($660 million of $1,123 million in the best guess scenario, or 59%) are attributable to the zero AOX scenario which is considered to have been somewhat probable in Québec (40%) and highly probable in Ontario (70%).

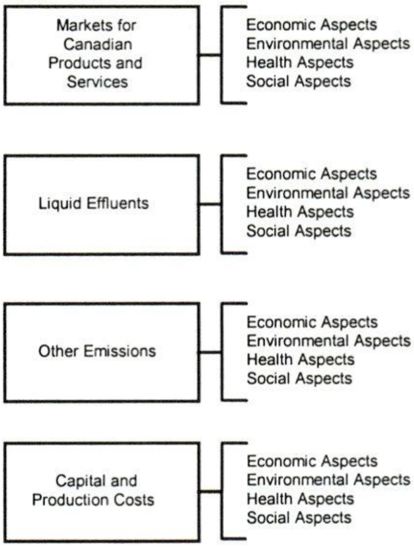
- As noted previously, the cost calculations are based on the conservative assumptions that the technologies of today (1997) would have been available at the time investment decisions had to be made and that the effectiveness of those technologies in reducing AOX emissions would have been properly appreciated. The magnitude of the costs calculated on the basis of the 1992 Simons report (3 to 5 times higher) gives an indication of what might have happened if stringent regulations had been implemented with little notice.

- In the case of markets, the key variable is the projected present share of TCF pulp in the Germanic countries, in the absence of the research. The three scenarios posit a share varying from 40% to 60%. Moving from 40% to 60%, the impact on Canadian exports is increased from $323 million to $1,200 million. This represents an increase of 270% for a 20% difference in the underlying assumption.

6.2 ECONOMIC, ENVIRONMENTAL, HEALTH AND SOCIAL ASPECTS

In this section, we examine the economic, environmental, health and social implications of the impacts described in Section 6.1. These impacts are, in fact, the ultimate impacts on the right-hand side of our impact map, reproduced here as Figure 6.1.

Figure 6.1
Ultimate Impacts



The ultimate impacts include:

- AOX-related impacts on markets for Canadian pulp and paper products
- AOX-related impacts on liquid effluents and other emissions (none identified)
- AOX-related capital and production costs avoided
- Impacts on liquid effluents and other emissions from changes to pulp mill processes
- Impacts on capital and production costs from changes to pulp mill processes

6.2.1 Economic and Social Aspects

In this sub-section, we address the economic and social aspects of the ultimate impacts. However, because of the assumption there were no net AOX-related environmental impacts, and there is little information concerning the impacts on water quality and capital and production costs from changes to pulp mill processes, we concentrate on the economic and social implications of AOX-related impacts on markets, and AOX-related impacts on costs.

Three types of economic impacts can be described:

- ***Direct impacts*** are attributable to the activity that would be generated directly by the sale of pulp These include the salaries and wages paid to workers of the pulp mills, and the revenues earned by the companies.

- ***Indirect impacts*** are the economic impact of pulp mills' purchases of goods and services from other companies. For example, the value of the demand for chlorine and other chemical feedstocks by a pulp mill are an indirect effect on the chemical and chemical products industry.

- ***Induced impacts*** are the multiplied effects of the direct and indirect incomes earned through an economic activity. For example, with the wages earned working in a mill or as a forester, someone can purchase goods and services which become revenues for another economic agent. These revenues generate cycles of economic impacts which when added together form the induced effect. Induced effects are based on wages (and salaries), business income (profit), and investment income.

Induced impacts are sometimes calculated to promote an industry or activity. However, because of the promotional, rather than economic-analytical nature of these impacts, they are not accepted by the Government of Canada as a basis for policy or decision analysis.[51] Consequently, they are not included in this analysis.

[51] The principal reason for this view is that the unspecified nature of the economic activity leads to speculative conclusions that add very little information to an analysis (since such effects are always present).

The two most relevant ways to express these direct and indirect impacts are:

- ***Dollar value of the change in GDP***. The value of all goods and services produced in an economic region over a period of time by the residents of that region. Often, "GDP" and "value added" will be used as interchangeable terms.[52]

- ***Number of full-time equivalent (FTE) person-years of employment created (or lost)***. A unit that measures the normal amount of work performed by one employee in an industry sector over one year. It does not necessarily correspond to the number of employees in a sector. For example, two people working half time for one year would yield one FTE.

Market-Based Impacts

The calculation of the total economic impact of the hypothetical loss of pulp sales in European markets is based on the input-output model of Canada and the provinces.

Input-output tables represent the most detailed accounting of economic activity available for Canada. If the lost pulp exports are characterized as a series of lost commodity sales, then the accounting of the model will estimate how that loss will be distributed throughout the economy—showing not only the decline in demand for pulp, but the resulting effects on suppliers of goods and services to the pulp mills, including the demand for labour (Appendix I describes the use of the model in additional detail).

The first step was to define the nature of the economic input to the input-output model (i.e., foreign sales of pulp) and to obtain from the model unit responses to this change (e.g., GDP per $million of sales). The result is provided in Appendix I.

Secondly, from Section 5.2, we obtained the value of Canadian exports that were potentially preserved and the portion of the impacts attributable to NWRI (see Table 6.4).

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[52]GDP can be measured in one of three ways:

- Income Based. The value of all the incomes in the economy including labour income, interest income, and revenues received by governments as indirect taxes (less subsidies).
- Expenditure Based. The value of all things purchased in the economy, including consumer purchases of goods and services, investments in equipment and additions to inventories, government purchases of goods and services, and purchases made by foreigners (less the value of what we buy as imports).
- Value Added. The sum the value of all the products produced in the economy less the cost of making those products.

By accounting definition all three methods will arrive at the same value for GDP.

Table 6.4
Attribution of NWRI Impact on Export Markets Millions of 1993 Dollars

Scenario		1993	1994	1995	1996	1997 to 2012	Total
Low Impact	Total	$0	$2	$56	$99	$166	$323
	NWRI 60% attribution	$0	$1	$34	$59	$100	$194
Best Guess	Total	$0	$23	$172	$211	$355	$762
	NWRI 75% attribution	$0	$17	$129	$158	$266	$571
High Impact	Total	$0	$43	$289	$324	$542	$1,198
	NWRI 90% attribution	$0	$39	$260	$292	$488	$1,078

Using these ranges, the input-output simulation yields the following results (Table 6.5):

Table 6.5
Direct and Indirect Effects of NWRI Research on the Canadian Economy by Year and Impact Scenario

Scenario	Socio-economic Measure	1993	1994	1995	1996	1997 to 2012	Total[53]
Low Impact	GDP (Millions of 1993 Dollars)	$0	$1	$25	$44	$74	$144
	Employment (FTE)	0	18	399	704	1,185	2,306
Best Guess	GDP (Millions of 1993 Dollars)	$0	$13	$96	$118	$199	$425
	Employment (FTE)	0	203	1,534	1,882	3,167	6,786
High Impact	GDP (Millions of 1993 Dollars)	$0	$29	$193	$217	$364	$803
	Employment (FTE)	0	461	3,084	3,461	5,798	12,804

The model also provides a breakdown of these results by type of income and by industry.

This breakdown indicates that nearly 72% of the impact is realized in the form of labour income (see Table 6.6).

[53] To add GDP and employment benefits over multiple years, we consider the equivalent as a one-time increase in GDP and employment (occurring in 1993).

Table 6.6
Direct and Indirect Effect on GDP by Income Type, in Millions of 1993 Dollars

Scenario	Labour Income	Business Income	Total
Low Impact	$103	$41	$145
Best Guess	$305	$121	$425
High Impact	$575	$228	$803

The breakdown also indicates, not surprisingly, that the GDP impact falls heavily in the paper and allied products (in which the pulp production is a sub-industry). The other most impacted industries are transportation and logging & forestry (see Table 6.7).

Table 6.7
GDP by Industry Sector, in Millions of 1993 Dollars

Industry Sector	Low Impact	Best Guess	High Impact	Percent Distribution
Paper & Allied Products	$46	$136	$257	32%
Transportation	$15	$45	$85	11%
Logging & Forestry	$14	$41	$78	10%
Other Utility	$11	$34	$64	8%
Wholesale Trade	$10	$30	$55	7%
Wood	$8	$23	$43	5%
Chemical & Chemical Products	$5	$14	$28	3%
Finance & Real Estate	$4	$12	$22	3%
Business Service	$4	$12	$22	3%
Royalties on Resources	$4	$11	$22	3%
Total Top Ten	$122	$359	$677	84%
Total All Industries	$145	$425	$803	100%

In terms of employment, the Best Guess scenario estimated employment benefit of NWRI's efforts is approximately 6,800 FTE. Table 6.8 shows how this employment was distributed among industries and between direct and indirect effects.

Table 6.8
Direct and Indirect Effect on Employment In Full Time Equivalent Jobs
(Best Guess Scenario)

Industry Sector	Direct	Indirect	Direct & Indirect	% Distribution
Paper & Allied Products	2,000	61	2,061	30%
Transportation	269	559	828	12%
Logging & Forestry	2	636	638	9%
Wholesale Trade	116	477	593	9%
Wood	0	471	471	7%
Retail Trade	1	352	352	5%
Other Service	1	313	314	5%
Business Service	0	274	274	4%
Other Utility	0	170	170	3%
Finance & Real Estate	0	153	153	2%
Total Top Ten	2,389	3,466	5,856	86%
Total all Industries	2,401	4,385	6,786	100%

It should be noted that most, but not all, direct jobs protected are in the paper and allied products industry. The other direct jobs, in transportation for example, would be positions with firms in the pulp industry but in a function separate from pulp production (e.g., truck drivers are counted in the transportation industry even though they may work for pulp producers).

The distribution of employment across industries for the low and high impact scenarios would be the same as in the above table, though the totals would be accordingly smaller and larger.

Cost-Related Impacts

In the case of market-based impacts, the value of European pulp sales constituted new money for the Canadian economy which otherwise would not have been available. As a result, the direct and indirect impacts of these sales are net benefits to Canada.

In contrast, the money that, in the absence of NWRI, would have been spent on environmental technology would have contributed to the Canadian economy regardless of how it was spent. The relevant question is to establish the difference between the effect of spending on environmental technology and the effect of other uses of those funds (note that in this section we deal solely with social and economic effects whereas health and environmental effects are dealt with in Section 6.2.2).

Two types of effect are possible:

- Impacts on the economy through capital and operating expenditures[54]
- Returns on the investment.

With respect to the impacts of capital and operating expenditures, there is no basis to establish what (if any) differences might occur. Both types of investments would likely lead to spending in Canada and abroad, but there is no reason to suppose that domestic operating is more likely in one case than the other. However, we do have a basis upon which to compare returns on investment. In the case of investments in AOX abatement technology, there would have been no financial return whereas the alternative investments could be expected to generate such a return.

To calculate what this return might have been, we make the following assumptions:

- Alternative investments would earn a rate of return of 5%. This is a conservative assumption based on the rough average of Treasury bill rates of return over the past four years (see Table 6.9).[55]

Table 6.9
Rates of Return on Treasury Bills

Year	1993	1994	1995	1996
Average 90 day T-Bill[56]	4.91%	5.42%	6.98%	4.30%

- The investments would take place in 1997. This is a simplification: in reality some investments would undoubtedly have occurred earlier and others later.

- A portion of the financial return (estimated at 40%) would be paid out to foreign investors and therefore would be unavailable to the Canadian economy.

From Section 5.2, we obtain the value of the costs avoided and the portion of these savings attributable to NWRI (see Table 6.10).

[54] These impacts include the hypothetical expansion of markets for environmental technologies (AOX abatement measures) and services as mentioned in Section 4.2.

[55] Treasury bill rates are low because of the low risk associated with them.

[56] Canadian Economic Observer, Historical Statistical Supplement 1995/96; Statistics Canada 11-210-XPB.

Table 6.10
NWRI Impact on Compliance Costs (Millions of 1993 Dollars)

Scenario		Capital Costs	Discounted Value of Operating Costs	Total
Low Impact	Total	$1007	$50	$1,057
	NWRI 60% Attribution	$604	$30	$634
Best Guess	Total	$1,119	$55	$1,174
	NWRI 75% Attribution	$839	$41	$880
High Impact	Total	$1,231	$61	$1,291
	NWRI 90% Attribution	$1,008	$55	$1,163

Calculating the effect on GDP and employment of the financial return on the alternative investment of these savings requires a five-step process (Table 6.11).

- First, we need to convert these savings from 1993 dollars to 1997 dollars (this is done by compounding at a rate of 5%). The best guess result is $1,180 million.
- Second, we calculate the annual value of a 5% return on this investment. The best guess result is $59 million.
- Third, we convert this annual revenue to 1993 dollars by discounting at a rate of 15% (once again, this is a conservative assumption). The best guess result is $201 million.
- Fourth we subtract the amount of the estimated foreign claims on this investment return (40%).[57] The best guess result is a $121 million increase in GDP.
- Finally, we calculate the number of FTE created (or preserved) using the overall average for the Canadian economy (i.e., 18 FTE per $million). The best guess result is 2,200 FTE.

[57] Bank of Canada Review, Summer 1997.

Table 6.11
Effect of Hypothetical Alternative Investment of Cost Savings on GDP and Employment

Scenario	Low Impact		Best Guess		High Impact	
	Total	NWRI 60%	Total	NWRI 75%	Total	NWRI 90%
Savings ($million 1993)	$1,057	$634	$1,174	$880	$1,291	$1,163
Savings ($million 1997)	$1,417	$850	$1,574	$1,180	$1,731	$1,558
Annual Investment Income @ 5% ($million)	$71	$43	$79	$59	$87	$78
Value of Income ($million 1993)	$241	$145	$268	$201	$295	$266
Domestic Portion of Income ($million 1993)	$145	$87	$161	$121	$177	$159
Employment (FTE)	2,600	1,600	2,900	2,200	3,200	2,900

Total Effect of Market and Cost Impacts

Adding the effects on GDP and employment of the market-based and cost-based impacts over the period 1993-2012, the effect of the NWRI research is estimated to be (for the best guess scenario):

- $546 million increase in GDP ($425 million due to markets preserved + $121 million due to costs savings)
- Approximately 9,000 person years of employment (6,800 due to markets preserved +2,200 due to costs savings).

The results for all scenarios are provided in Table 6.12.

Table 6.12
Summary of Effects on GDP and Employment of NWRI Research

Scenario		Low Impact	Best Guess	High Impact
Market Based	GDP ($million 1993)	144	425	803
	Employment (FTE)	2,300	6,800	12,800
Cost-Based	GDP ($ million 1993)	87	121	159
	Employment (FTE)	1,600	2,200	2,900
Total	GDP ($ million 1993)	231	546	962
	Employment (FTE)	3,900	9,000	15,700

These totals represent the one time (1993) equivalent of the aggregate changes in GDP and employment (which vary over time). The peak annual change occurs in the 1996-97 period when market effects are at their maximum and the capital for AOX-technology is required. The peak changes are equal to the market-based effects in 1996 (from Table 6.5) plus the cost-related impacts (from Table 6.11). The results (for the Best Guess Scenario) are:

- An increase in GDP of $177 million ($118 million due to markets preserved + $59 million due to cost savings). This compares with the total GDP in that year of $675 billion.

- An increase in employment of approximately 3000 FTE (approximately 1900 due to markets preserved + 1100 due to cost savings[58]). This compares with the total employment in that year of 13.6 million.

6.2.2 Environmental and Health Aspects

In principle, there are environmental implications associated with all the ultimate impacts.

Preserving markets for Canadian pulp means that the associated activities (tree harvesting, transportation and the operation of pulp mills) and their impacts will also be "preserved". Although some of these impacts are mitigated (e.g., by regulations), others remain (pollution and lost opportunities for other forest uses, such as camping, hunting, nature watching, etc.). Ideally, royalties and taxes should be set sufficiently high to compensate society for the remaining pollution and lost opportunities. Whether this is the case here is debatable, however, given the level of effort required and the methodological difficulties involved, this study makes that assumption and does not include either in the impact analysis.[59]

Avoiding unnecessary costs may also have environmental implications if it leads to investments in polluting activities. In this study, we assume that the level of activity associated with pulp mills is not affected by the costs savings and that the savings are directed to other investments whose net environmental effect is zero.

Given these assumptions and the fact that there are no known environmental benefits (or costs) associated with changes to other emissions, our focus is on the environmental implications of changes in the quality and quantity of liquid effluents.

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[58] Calculated on the basis of the economy average of 18 FTE/$million.

[59] It should also be noted that while this study accounts for some of the benefits to society of preserved markets (e.g., GDP and jobs), it does not consider other benefits that are more difficult to assess (e.g., social cohesion, lower poverty, improved infrastructure, corporate donations, etc.)

Potential environmental and health implications are primarily related to the effects on aquatic organisms associated with potential changes in ambient water quality, which are in turn associated with changes in the characteristics of the effluents.

In Section 5.1.4, the case was made that there is no evidence to determine if the net environmental effect of further reductions to AOX would be positive or negative. Consequently, our focus is on the impacts of the changes in effluent water quality associated with potential measures to deal with sources of toxicity identified in Section 5.3:

- Black or cooking liquors
- Digester condensates
- Breakdown of resin acids in secondary treatment
- Additives (e.g., defoamers).

One problem with this task is that, while effects on individual aquatic organisms (tissues, organs and whole fish) have been documented, effects on specific populations have not been conclusively demonstrated, nor have any downstream human health impacts been documented. Furthermore, some of the observed effects on organisms are related to the observation of biochemical indicators, such as increased activity of liver Mixed Function Oxygenase (MFO) enzymes, rather than whole organism effects.[60]

On the other hand, the following arguments can be made:

- Although evidence of population and community-level impacts on specific species in affected ecosystems has not been documented, this could be due to migration from other ecosystems. The fact that such migration may be occurring should not obscure the fact that the impacts may be real.

- A further reason for the lack of observed population and community-level impacts may be that the most sensitive species have already disappeared from affected ecosystems.

- The chemistry, transport, fate and effects of the pollutants are so complex that it may never be possible to conclusively link population and community-level impacts to the effluents.

- A reasonable precaution to protect aquatic organisms and human health is to adopt the objective that aquatic organisms should not be exposed to levels of contaminants which cause a physiological response.[61]

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[60]Although elevated levels of MFO have not been demonstrated to cause harm, they are thought to be a reliable indicator of exposure to chemical contamination. Research underway may soon demonstrate a conclusive link to reproductive and immune system effects.

[61]Notwithstanding the difficulties in observing population effects in actual receiving waters, research is presently

In fact, Environment Canada, in recognition of the extreme difficulty in evaluating population level effects (because of the large number of variables and the mobility of the fish) has adopted the objective that there should be no observed organism effects.

Table 6.13 summarizes the effects that may be associated with the effluent streams discussed in Section 5.3.[62]

Table 6.13
Potential Effects of Pulp and Paper Mill Effluent Streams

Effluent Stream	Effect	Notes
Black liquor from digesters	MFO Effects Reproductive Effects (?)	Setosterol is a form of plant estrogen present in black liquor. Hormonal changes have been observed but since expected effects on eggs have not, there is some question concerning the bioavailability of setosterol.
Digester Condensates	MFO Effects Reproductive Effects (?)	The digester condensates contain substances analogous to hormones but their effects have not been demonstrated.
Resin Acids	MFO Effects	
Additives (e.g., defoamers)	Reproductive Effects (?)	Nonyl phenol, which is a component of some additives, has been shown to cause reproductive effects but these effects have not been linked to the effluents.

Although the evidence to link specific effluent streams to organism effects is not yet substantial, the expectation is that further evidence will emerge as specific mills implement the changes described in Section 5.3. If so, Environment Canada expects that there could be substantial mitigation or elimination of some of the documented impacts of pulp and paper effluents.

If this expectation is realized, the following observed impacts in fish could be reduced: [63]

underway to model population impacts in theoretical situations. One study, being undertaken by the Oak Ridge National Laboratory, in Tennessee, is using a computer model to predict population impacts from observed effects. Another study is modelling the effects of different stresses on fish populations in the Finger Lakes, in New York state. Studies such as these may yet provide better estimates of the overall impact of pulp mill effluents and the potential benefits of pollution prevention and control measures.

[62]Source: Conversations with J. Carey and K. Munkittrick (NWRI).

[63]Sandström, O. 1996. In Situ Assessments of the Impact of Pulp Mill Effluent on Life-History Variables in Fish. In *Environmental Fate and Effects of Pulp and Paper Mill Effluents*, (M.R. Servos, K.R. Munkittrick, J.H. Carey and G. Van Der Kraak, eds.), St. Lucie Press, Boca Raton, Florida.

- Stimulated growth rates
- Slower sexual maturation (which may indicate a significant negative impact on populations)
- Effects on size at maturation (both increases and decreases)
- Increased mortality
- Reduced gonad size
- Effects on fecundity (both increases and decreases)
- Reduced egg sizes (associated with increased fecundity)
- Reduced sperm motility (but not associated with reduced fertilization potential)
- Reduced larval growth rates
- Reduced size
- Increased prevalence of malformations
- Increased larval mortality.

Although the prevalence of these effects and their reliability as indicators of exposure to pulp mill effluent varies, the overall message is that there may be significant impacts occurring that have the potential to affect organisms. For example, in a series of studies at Jackfish Bay, Ontario, NWRI found evidence of increased age to maturity, smaller gonads, reduced fecundity with age in females, and a reduction in male secondary sexual characteristics.[64] These effects would logically lead to decreased ability to respond to population stresses.

6.3 VALUE FOR MONEY ASSESSMENT

The direct cost of NWRI's research was described in Table 3.2. In order to compare these costs to the benefits, we convert them to 1993 dollars (see Table 6.14).

Other costs identified involved the harvesting of a few thousand fish. However, the number of fish affected is not mathematically significant relative to the fish populations potentially affected by the research activities.

[64]Munkittrick, K.R., Servos, M.R., Carey, J.H. and Van Der Kraak, G.J. 1996. *Environmental Impacts of Pulp and Paper Wastewater: Evidence for A Reduction in Environmental Effects at North American Pulp Mills Since 1992.* Burlington and Guelph, Ontario.

Table 6.14
1993 Value of NWRI Costs

Year	$million (1993)
88/89	0.62
89/90	0.63
90/91	1.04
91/92	1.1
92/93	1.26
93/94	1.56
94/95	2.79
95/96	2.31
96/97	1.76
Total:	**13.07**

For the $13 million, Canadians received environmental regulations of pulp mills based on sound science. They are also likely to benefit from future improvements in water quality and reduced effluent toxicity. Coincidentally, the results of the science helped Canadian industry protect $762 million of export sales (based on the best guess scenario) and avoid paying $1.17 billion in unnecessary compliance costs. After attributing NWRI's share of the responsibility for these impacts, the benefits for all Canadians (not just the pulp industry) can be summed up by the $546 million contribution to GDP and the 9000 FTE over the period 1993-2012.

These results reflect ratios of $42 of GDP for each dollar of research and $1,444 of research per FTE of employment created.

7. CONCLUSIONS

7.1 OBSERVATIONS ON THE EVALUATION METHODOLOGY

Our experience in conducting this evaluation suggests a number of observations:

- It is possible to conduct a credible, if somewhat imprecise, evaluation of the impacts of public good R&D even if the research is relatively recent and the impacts are spread out over many years.

- Such an analysis must be based in part on assumptions, the nature of which can have a significant impact on the findings. It is therefore essential to make the assumptions explicit.

- It is easier to evaluate cost and market impacts than environmental impacts, particularly when those impacts are unclear.

- Impact maps provide a useful tool for visualizing the threads that link the research to ultimate impacts. Impact maps also provide a mechanism for explicitly considering assumptions concerning the priority impacts and linkages.

- Attribution of research results to specific programs can most effectively be handled through a proportionate attribution of credit for the results. Attribution of impacts to those results is best completed by determining the incremental impacts.

- Interviews are important for gathering the information and data necessary to identify, describe and quantify impacts. However, it is necessary to balance the need for information with the need to keep the interviews focussed, clear and short. Consideration must be given to dealing with information that may be contradictory, or of varying relevance.

- Because of the nature of the analysis required, detailed knowledge of events surrounding the research is essential. Thus, the analysis must engage the key players who were involved in the application of the R&D results; this involvement must be significant and recurring, at strategic points throughout the duration of the analysis. While such a contribution is essential, it raises the possibility of bias of the results; therefore, verification of key inputs, transparency of assumptions, and other aspects of the methodology must be utilized to reduce this possibility.

- An early focus of the research should be to identify and obtain key reference documents. Once again, the assistance of the key players who were involved in the application of the R&D results is essential.

- The construction of scenarios is a useful way to deal with uncertain information, particularly when speculation is required to establish hypothetical past or future situations.

- Input-output modelling is a useful method to identify the GDP and employment implications of foreign sales. However, to identify the implications of cost savings, such modelling can only be used if there is good information concerning alternative investment options. Otherwise less precise methods, based on generic assumptions concerning rates of return can be used.

- The nature of this case may be unique in that a significant portion of the benefits were associated with the fact that an event (regulation) did not occur. This reversed the usual approach to identifying incremental impacts. The case was further complicated by the fact that the provinces also played a role, occasionally adopting regulations that offset potential impacts of the research. Although these characteristics posed interesting challenges, they were not incompatible with the methodology.

7.2 R&D IMPACTS

This evaluation has identified three main impact threads for the R&D on pulp and paper effluent toxicity undertaken by NWRI:

- ***Thread 1***. The impacts on liquid effluents and other emissions, and costs resulting from pollution prevention and control measures that were not required because of changes to regulations on AOX that occurred as a result of the knowledge on AOX provided by NWRI.

- ***Thread 2***. The impacts on markets for Canadian pulp and paper products from changes in purchasing practices that occurred as a result of the knowledge on AOX provided by NWRI.

- ***Thread 3***. The impacts on liquid effluents and other emissions, and costs from future changes to pollution prevention and control measures that are likely to be implemented as a result of NWRI knowledge concerning the sources of toxicity within pulp and paper processes.

Thread 1 -- AOX-Related Impacts on Liquid Effluents and Other Emissions, and Capital and Production Costs Avoided

Our conclusions are as follows:

- NWRI was the key contributor to the research result that AOX is not an appropriate parameter to regulate the toxicity of pulp and paper mill effluent.

- This result influenced regulators at the Federal and provincial levels in designing regulations. In the case of the Federal regulations, AOX was not included; in some provinces, AOX limits were not as stringent as they might otherwise have been.

- This saved the Canadian pulp and paper industry between $1.06 billion to $1.29 billion in capital and production costs. The best guess is a figure of $1.17 billion.

- Based on the analytical approach taken, the portion of these savings attributable to NWRI's research was between $640 million and $1.16 billion. The best guess is $880 billion.

- Based on Environment Canada's view, there is no evidence that any environmental benefits were foregone as a result of not implementing AOX regulations.

Thread 2 -- AOX-Related Impacts on Markets for Canadian Pulp and Paper Products

Our conclusions are as follows:

- NWRI was the key contributor to making consumers aware that AOX is not an appropriate parameter to measure the toxicity of pulp and paper mill effluent.

- This result influenced pulp consumers (particularly in Europe) to moderate their preference for TCF pulp and to continue purchases of ECF and conventional pulp.

- Since Canada produces virtually no TCF pulp, this allowed Canadian pulp mills to maintain a larger share of the European market than they otherwise would have.

- The value of the market that was protected was between $323 million and $1.20 billion. The best guess is a figure of $762 million.

- Based on the analytical approach taken, the portion of this market protection attributable to NWRI's research was between $194 million and $1.08 billion. The best guess is $572 million.

Thread 3 -- Impacts on Liquid Effluents and Other Emissions (and Capital and Production Costs) from Changes to Pulp Mill Processes

Our conclusions are as follows:

- NWRI was the key contributor to the research conclusion that Canadian pulp mill effluent (whether bleached with chlorine or not) causes sub-lethal toxic effects analogous to effects first observed in Sweden.

- NWRI has been and continues to be a key contributor to the development of test methods to evaluate the toxicity of effluents.

- NWRI was a significant contributor to the identification of several potential sources of toxicity within mill processes, including:
  - Black liquor from digesters
  - Digester condensates
  - Breakdown of resin acids in secondary treatment
  - Use of certain additives (e.g., defoamers).

- Pollution prevention and control measures which may be implemented, at least partially in response to this research, would improve effluent and ambient water quality and could contribute significantly to mitigating or eliminating a variety of sub-lethal toxic effects in fish (including reproductive effects). There is no evidence of any net environmental costs or benefits associated with changes to other emissions.

Economic, Environmental, Health and Social Aspects

Our analysis indicates that the markets preserved and costs avoided as a result of NWRI research resulted in an increase to GDP of between $231 million and $962 million. The best guess is $546 million. The research also resulted in the creation (preservation) of between 3,900 and 15,700 FTE (person years of employment). The best guess is 9000 FTE . In addition, NWRI's work is likely to lead to improvements in effluent water quality that will reduce physiological effects on fish (particularly reproductive effects) and reduce the risk of unknown human health impacts.

Summary

The analysis conducted indicates that the R&D on pulp mill effluent toxicity conducted by NWRI during the period of 1988 to 1996 was responsible for cost savings to the Canadian pulp and paper industry in the order of $1.17 billion (based on the Best Guess scenario). It was also responsible for protecting markets for the products of the pulp and paper industry worth approximately $762 million (also based on the Best Guess scenario). The effect of these impacts was a contribution to the GDP in the order of $546 million and the creation or preservation of 9,000 person-years of employment (based on the Best Guess Scenario).

In addition the research has identified potential sources of toxicity within mill processes. These findings may lead to measures that yield future environmental benefits (as yet unclear) at modest cost.

The analysis also considered a large number of other potential impacts and impact threads but did not examine them in detail either because they were not expected to be significant, or because the relevant information was not readily available. These other impacts included:

- Contributions to building scientific capacity.
- Knowledge of other emissions from pulp and paper mills.
- Knowledge of effluents from other industries.
- Measures taken in other countries.
- Markets for Canadian products and services -- resulting from the commercialization of effluent testing methodologies.
- Markets for Canadian products and services (environmental technologies and services) -- resulting from measures taken in other countries based on the results of the research.
- Markets for Canadian products and services (environmental technologies and services) -- resulting from measures taken in Canada.
- Pollution prevention, control and monitoring measures -- implemented as a result of changes in purchasing practices.
- Pollution monitoring measures -- resulting from the development of effluent testing methodologies.

These benefits are generally expected to be positive, although this expectation was not tested in this analysis.

In addition, it is possible that there may be other unknown impacts (past, present or future) which could be significant but were not identified.

APPENDIX A

- **List of Steering Committee Members**

List of Steering Committee Members

Name	Position/Address	Phone/Fax/E-mail	Status
Cynthia Wright	DG Corporate Management and Review Environment Canada Terraces de la Chaudiere 10 Wellington Street, 26th Floor Hull, PQ K1A 0H3	T: (819) 953-2091 F: (819) 953-3388	Chair
Jean Leclerc	Evaluation Manager, Review Branch Environment Canada Terraces de la Chaudiere 10 Wellington Street, 26th Floor Hull, PQ K1A 0H3	T: (819) 997-3948 F: (819) 994-7321	Secretary
Mike Beale	Director, Economic Issues Branch Environment Canada Terraces de la Chaudiere 10 Wellington Street, 22nd Floor Hull, PQ K1A 0H3	T: (819) 953-9459 F: (819) 997-0709	Member
Dave Black	Economist, Policy Directorate Corporate Policy Group Environment Canada Terraces de la Chaudiere 10 Wellington Street, 22nd Floor Hull, PQ K1A 0H3	T: (819) 997-1158 F: (819) 997-0709	Alternate
John Carey	Executive Director National Water Research Institute Canada Centre for Inland Waters 867 Lakeshore Road, P.O. Box 5050 Burlington, ON L7R 4A6	T: (905) 336-4625 F: (905) 336-6444	Member
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Roger Street	Director, Environmental Adaptation Research Group Atmospheric Environment Service Environment Canada 4905 Dufferin Street, Room 3S208 Downsview, ON M3H 5T4	T: (416) 739-4271 F: (416) 739-4297	Member

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André Jacquemot	Resource Economist Environmental Systems Branch Environment Canada 351 St. Joseph Blvd., 7th Floor, PVM Hull, PQ K1A 0H3	T: (819) 953-1427 F: (819) 994-6787	Alternate

APPENDIX B

- **Interview Guide and Questions**

Introductory Letter to Interview on Pulp and Paper Effluent R&D

Thank you for agreeing to help in evaluating the impact of Environment Canada's research and development on pulp and paper mill effluents. This information package contains some explanatory material and a description of the subjects proposed for your telephone interview which is scheduled for (date and time).

Environment Canada has retained the services of Marbek Resource Consultants and SECOR Inc. to develop a methodology to identify, describe and measure the impacts of Environment Canada's R&D in support of public policy. To accomplish this, a case study approach is being used. Research on the toxicity of pulp and paper mill effluents conducted by the National Water Research Institute (NWRI) and the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) in the period April 1988 to December 1996 is one of two cases chosen for the study.[1]

Prior to release of new federal pulp and paper effluent regulations in 1992, NWRI (in the rest of this letter and in the questionnaire, "NWRI" is used to mean both NWRI and GLLFAS) studied sub-lethal toxicity among fish populations in receiving waters of mills with different bleach processes and effluent treatment systems. Impaired reproductive responses and induction of liver detoxification enzymes in wild fish were observed at sites receiving discharges from mills with and without chlorine bleaching. This research influenced the conclusion of the federal government in 1992 that adsorbable organic halogen (AOX) was not a suitable regulatory parameter for pulp mill effluent. Continuing research has investigated the causes of sub-lethal toxicity observed in aquatic species in pulp mill receiving waters. Elements of this work include field and laboratory studies of the toxicity of whole effluent and components of effluent, the changes in toxicity resulting from mill process changes, and the environmental fate of mill effluents. Also included are development of laboratory test methods to support the research, and communication of research results to professional and public audiences.

Interviews with subject experts and literature reviews are being done to examine the validity, strength and nature of the proposed linkages between R&D and present and future impacts and to establish the relative contributions of NWRI research and other influences to these present and future impacts.

You were recommended as a candidate for interview because of your knowledge of one or more impacts under consideration and of the research done by NWRI on pulp and paper mill effluents. The interview will solicit your opinions on the nature of the impacts and the relative importance of NWRI research to various impacts such as regulatory measures, changes in markets and process and equipment upgrades in mills. In general, you will be asked how influential the NWRI work has been to decisions and actions taken and what consequences the research might have in the next five to ten years.[2]

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[1] The other case involves research on stratospheric ozone depletion by the Atmospheric Environment Service.

[2] Because our objective is to attribute the correct portion of the overall impacts to the NWRI research, we will ask you to speculate on what might have happened in the absence of the NWRI research and to quantify, if possible,

The particular topics for which your opinions and expertise are sought are listed in the attached Interview Guide. Each listing includes possible impacts of the research as well as the names of possible contributors other than NWRI to these impacts.

In order to maximize the efficiency of the interview and minimize your time commitment, we ask you to review the topics and gather your thoughts before the interview.

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the relative contributions of the various influences on each impact.

INTERVIEW GUIDE

Note: Only applicable questions are included for each interview.

1. Worldwide knowledge base on toxicity of pulp and paper mill effluents

Potential Impacts:

To which aspects of knowledge about effluents did NWRI research during the period 1988-96 contribute significantly? Please verify and, if necessary, complete the following list:

- knowledge that pulp and paper mill effluent leads to sub-lethal toxicity in aquatic species and that this effect is not confined to the European situation
- knowledge of limits to the use of AOX as a proxy for toxicity
- knowledge of the role of classes of organochlorine compounds in effluent toxicity
- knowledge of causes of effluent toxicity within pulp and paper processes and toxicity reduction strategies
- development or standardization of testing methodologies
- other

Contribution of NWRI:

In each case, what would have happened if NWRI had not participated?

In cases where NWRI made a difference, how would you rate the relative importance of the contributions of the following parties to each of the impacts indicated above?

- NWRI
- Canadian provinces
- United States EPA, NCASI
- Sweden and Finland
- university research groups
- private sector
- other

2. Federal Regulations and other Instruments

Potential Impacts:

What regulatory provisions were influenced by NWRI research? Please verify and, if necessary, complete the following list:

- AOX not included in federal pulp and paper mill effluent regulations
- provisions on environmental effects monitoring
- regulatory and/or non-regulatory programs that are likely to be implemented in the future
- other

Contribution of NWRI:

In each case, what would have happened if NWRI had not participated?

In cases where NWRI made a difference, how would you rate the relative importance to decisions taken on the above provisions among the following:

- Worldwide scientific knowledge base on relevant issues (including a portion of which could be attributed to NWRI)
- NWRI assistance in interpreting the science to Environment Canada staff
- NWRI communications to the private sector and ENGOs
- cost to industry
- CEPA assessment of pulp mill effluents
- other policy considerations

3. Provincial Effluent Regulations and other Instruments

Potential Impacts:

In relation to specific provinces (New Brunswick, Nova Scotia, Québec, Ontario, Alberta, B.C.), what regulatory provisions or mill licensing conditions were influenced by NWRI research? Please verify and, if necessary, complete the following list:

- AOX not included in regulations
- maximum allowable AOX levels in regulations
- schedule for implementation of AOX limits
- provisions on environmental effects monitoring
- regulatory and/or non-regulatory programs that are likely to be implemented in the future
- other

Contribution of NWRI:

In each case, what would have happened if NWRI had not participated?

In cases where NWRI made a difference, how would you rate the relative importance to decisions taken on the above provisions among the following:

- Worldwide scientific knowledge base on relevant issues (including a portion of which could be attributed to NWRI)
- direct NWRI information to provincial regulators
- other policy considerations

Have the provinces made use of NWRI-developed testing methodologies? If so, to what extent?

4. Pollution Prevention, Control and Monitoring Measures

Potential Impacts:

What measures were influenced by NWRI research? Please verify and, if necessary, complete the following list:

- process changes implemented
- process changes not implemented that otherwise might have been
- pollution control measures implemented
- pollution control measures not implemented that otherwise might have been
- environmental monitoring measures
- measures that are likely to be implemented in the future
- other

Contribution of NWRI:

In each case, what would have happened if NWRI had not participated?

In cases where NWRI made a difference, how would you rate the relative importance of the following influences on the above impacts:

- federal regulations
- provincial regulations
- cost
- market demand
- knowledge of the toxicity of effluents (please identify the main sources of this knowledge)

- direct discussions with NWRI
- other

Has industry make use of NWRI-developed testing methodologies? If so, to what extent?

5. Markets

Identification of Impacts:

What markets were influenced by NWRI? Please verify and, if necessary, complete the following list:

- European markets for Canadian pulp and paper products (gained, retained or lost)
- American markets for Canadian pulp and paper products (gained, retained or lost)
- other

Description of Impacts

What was the impact on these markets of NWRI's contribution to world knowledge of pulp mill effluent toxicity and specific information efforts to consumers, governments and the public?

What would have happened in the absence of NWRI?

6. Effluent Water Quality

Identification of Impacts:

What changes in water quality were influenced by NWRI? Please verify and, if necessary, complete the following list:

- increased toxicity due to measures not implemented
- decreased toxicity due to measures implemented
- decreased toxicity due to measures likely to be implemented
- other eg. quantity of effluent, suspended solids, oxygen demanding matter

Description of Impacts

What was the impact on water quality of the various measures identified in section 4?

7. Effects on other Emissions

Identification of Impacts:

What changes in other emissions were influenced by NWRI? Please verify and, if necessary, complete the following list:

- increased or decreased air emissions
- increased or decreased solid waste emissions

Description of Impacts

What was the impact on these emissions of the various measures identified in section 4?

8. Capital and Production Costs

Identification of Impacts:

What costs were influenced by NWRI? Please verify and, if necessary, complete the following list:

- purchase of new equipment by producers
- premature replacement of equipment by producers
- conversion of equipment by producers
- process redesign by producers
- purchase of new materials by producers
- process innovation triggered by the new requirements
- cessation of operations by producers
- shortfalls of products for consumers
- changes in prices for consumers (as a result of changes in production costs)
- changes in prices for consumers (as a result of changes in their purchasing practices)

Description of Impacts

What was the impact on these costs of the various measures identified in section 4 and the market changes identified in section 5?

APPENDIX C

- List of Interview Subjects

List of Interview Subjects

Gary Amendola
Principal, Amendola Engineering

Dr. Richard Berry
Director of Research
Paprican

Lauren Blum
Environmental Defence Fund

Dr. John Carey
Executive Director, NWRI

Richard Cockram, Director
NLK Consultants Ltd. (UK)

Roger Cook, VP Environment
EB Eddy Forest Products Ltd.
Chair, CPPA Technical Committee on EEM

Richard Glandon
Forest Industries Group
Industry Canada

André Grondin
Québec Ministry of the Environment

François Guimont
RDG Environment Canada
Québec Region

David Halliburton, Head, Renewable Resources
Environment Canada

Connie MacDonald
Environmental Information Management Division
Environment Canada

Rory McAlpine, Commercial Counsellor
Canadian Mission to the European Union

Brian McClay
Sr. V.P. Government Relations
Canadian Pulp & Paper Association

Neil McCubbin
Consultant

Ross Miller
Counsellor (Economic)
Canadian Embassy, Bonn

Dr. Kelly Munkittrick
NWRI, formerly GLLFAS

Jay Nagendran, Head
Industrial Waste and Wastewater Branch
Alberta Ministry of Environment

Roy Parker, Biologist
Atlantic Region, Environment Canada

Douglas Pryke, Executive Director
Alliance for Environmental Technology

Les Reissner
Trade and Environment
Foreign Affairs and International Trade

Dr. Doug Reeve
Head of Pulp and Paper Centre
Associate Professor, University of Toronto

Dr. Olaf Sandstrom
National Board of Fisheries
Sweden

R.A. (Tony) Shebbeare for Maldwyn Thomas
Director, CPPA, Brussels

Marc Sinotte
Environmental Analyst - Aquatic Ecosystems
Quebec Ministry of Environment

Ed Turner, Manager
Technical Services Section
Ontario Environment and Energy

Harry Vogt, Manager
Technical Services and Special Wastes Section
B.C. Ministry of Environment, Lands and Parks

Wally Vrooman
Vice President Environment, Avenor

APPENDIX D

- List of Principal Reference Documents

List of Principal Reference Documents

Axegard, P., Carey, J., Folke, J., Gleadow, P., Gullichsen, J., Pryke, D.C., Reeve, D. W., and Swan B. (Draft, 1997) *Minimum-Impact Mills: Issues and Challenges.* Sweden, Canada, Denmark, Finland.

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VanNijnatten, D. L., Leiss, W., and Hodson, P.V. (Draft, 1997) *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada.* Kingston, Ontario.

APPENDIX E

- Estimate of Costs of R&D on Pulp and Paper Effluent Toxicity

Estimate of Costs of R&D on Pulp and Paper Effluent Toxicity
($million)

Year	Environment Canada						Fisheries and Oceans Canada					Other		Total
	A-Base Salary[1]	A-Base O&M[9]	A-Base Benefits[2]	A-Base Overhead[3]	Green Plan	Other DOE[4]	A-Base Salary[5]	A-Base O&M[13]	A-Base Benefits[10]	Green Plan	Other DFO	ISTC (University)[6]	Other External[7]	
88/89	222	148	45	163		160								738
89/90	215	143	43	157		155								713
90/91	235	157	47	172		206	114	114	23		35		15	1,118
91/92	254	169	51	186		73	78	78	16		55	170		1,128
92/93	249	166	50	182	70	70	83	83	17	106	45	140		1,259
93/94	269	179	54	197	170	101	102	102	20	81	105	170		1,551
94/95	489	326	98	358	377	187	88	88	18	168	212	190	148	2,747
95/96	435	290	87	318		226	91	91	18	182	206	200	105	2,250
96/97	386	258	77	283		160	22	22	4	242	181		77	1,713
Total	2,754	1,836	551	2,016	617	1,337	579	579	116	779	839	870	346	13,216

[1] These figures were calculated on the basis of an estimate that 85% of the research activities were attributable to pulp and paper R&D (the rest being applied to municipal and refinery effluents). The breakdown between salary and O&M was estimated to be 60-40.

[2] These figures were calculated on the basis of 20% of salary costs.

[3] These figures were calculated on the basis of an estimate of total annual NWRI overhead of $5million and total program spending of approximately $15 million. The overhead for the pulp and paper R&D was calculated by applying the ratio of program spending (pulp and paper divided by total), to the overall NWRI overhead costs.

[4] These figures reflect funding from major Environment Canada ecosystem programs; specifically Great Lakes 2000, Fraser River Action Plan and Northern Rivers Basins Study.

[5] The breakdown between salary and O&M was estimated to be 50-50.

[6] These figures represent resources provided by Industry Canada as matching funding for universities.

[7] These figures include external sources of funding such as Mott Foundation Fellowships, the Canadian Electrical Association and funding for cooperative projects under agreements with pulp producers such as Noranda Forest Products.

APPENDIX F

- **Pulp Mill AOX Costs**
  (Based on McCubbin 1997 Report)

Estimate of costs for various levels of AOX control in Canadian mills

prepared for

Marbek Resource Consultants

by

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1. Summary

This report presents estimates of the cost of applying hypothetical regulations limiting AOX discharges from Canadian mills to:

- 1.5 kg/t
- 0.8 kg/t
- "low AOX" (approximately 0.2 kg/t, technology defined)
- "Zero" AOX ("Non-detectable" would be a better term).

1.1 Estimated Costs

The estimated capital costs and changes in direct annual operating costs that the Canadian industry would have had to incur for several alternative regulations limiting AOX discharges are shown in Table 1 below.

Costs are expressed in 1993 Canadian dollars, and are based on technology proven in 1993, except that the TCF option would have been considered risky in 1993, although it is now proven.

Capital cost includes all costs of retrofitting the necessary systems, including recovery system upgrades and increased chlorine dioxide generation capacity where appropriate. Engineering, construction supervision and similar items often considered as "indirect costs" are included. Land purchase is assumed to be unnecessary.

Operating and maintenance costs include chemicals, energy. labour and repairs, but no elements of depreciation, finance costs, or items related to the capital cost. Data shown represents the difference from 1993 base case operation of a mill which complies with the Federal regulations limiting discharge of dioxins and furans.

Table 1 Capital and changes in operating costs for various AOX discharge limitations

AOX, kg/t	Capital	Annual O&M	Notes
1.5	Nil	Nil	Mills that comply with dioxin regulation will comply with this level of AOX
0.8 (ECF)	67	35 cost	"Low capital, High-operating cost". Most popular in Canda
0.8 (OD)	1,177	105 saving	"High-capital, Low-operating cost". Most popular overseas
0.2	4,350	65 saving	Limit of proven technology in 1993
Non-detect	3,150	154 cost	Risky in 1993, proven in 1997

Costs are expressed in millions of 1993 Canadian dollars

Detailed mill-by-mill costs are appended.

1.2 Caveat

The costs presented herein are based on the best information on mill configurations that could be assembled within the budget restrictions for the study. They are based on the mill descriptions by McCubbin (1992), Lockwoods Pulp and Paper Directory, and information incidentally available to the author from the study of the scientific and commercial literature related to the Canadian pulp and paper industry, and attendance at industry conferences. There

2. Methodology

The process concept required to reach each level of AOX of interest was defined, and the extent to which each element is required in each mill was assessed on the basis of available information.

The capital and operating cost for each element was estimated using the US EPA's "Best Available Technology" Cost Model equations, and summed for each mill.

2.1 Technology required for various AOX levels

All AOX levels of interest are currently being attained by at least several mills in the world. The level of technology generally used and proven for each AOX level of interest was defined, on the basis of such experience, as shown in Table 2. In all cases, it is assumed that the mill has secondary treatment, and a level of process control typical of Canadian mills in the 1990's. In most cases, installation of the key technology mentioned will require some supporting technology, as discussed below.

In 1993, all Canadian mills discharged under 2 kg AOX/ton pulp, except that 4 mills without secondary treatment discharged between 2 and 3 kg/t. These mills were committed prior to 1993 to installing secondary treatment, and were in the process of doing so. This would reduce the AOX discharges below 2 kg/t pulp. Hypothetical regulations above 2 kg/t are therefore of little significance.

Table 2 Technology required to comply with various AOX discharge limitations

AOX discharge	Associated technology
1.5 kg/t	High chlorine dioxide substitution (> 70%) OR oxygen delignification (This level AOX will be attained by mills complying with dioxin limits)
0.8 kg/t	100% chlorine dioxide substitution (ECF without OD) OR oxygen delignification (OD without ECF)
0.1 to 0.3 kg/t	Extended cooking Oxygen delignification 100% chlorine dioxide substitution Low Kappa factor operation
Zero	Convert to TCF Install oxygen delignification Install ozone delignification Convert ClO_2 stages to hydrogen peroxide

"kg/t" refers to kilograms per Air Dry metric ton product.

upgraded. The extent of the upgrade will vary from essentially nothing to recovering sufficient black liquor to increase boiler load by 0.6 GJ/t pulp. An average increase of 0.3 GJ/t is assumed, since there is no information available on the current status of the existing mills[3].

There will normally be some decrease in evaporator hydraulic load. This is ignored in the estimates herein.

2.2.3 High chlorine dioxide substitution

Most mills will require to increase chlorine dioxide generation capacity when converting from low to high (or 100%) chlorine dioxide substitution.

The cost estimates herein assume that the chlorine dioxide plant can be upgraded, but will not require replacement. This is consistent with experience in most mills, although a few would require new systems, and a few would not require significant work.

2.2.4 Ozone delignification

Ozone is manufactured on site. A mill owned plant is assumed, so that the capital cost is included in the capital cost of the ozone delignification system.

Retrofitting ozone systems also impacts the recovery system as shown in Table 1. Appropriate costs are included in the estimates.

2.3 Capital costs

The capital costs were estimated for each mill on the basis of the cost model developed by McCubbin for the US EPA. The most model equations are publicly available, and has been reviewed and accepted by numerous parties, including many US paper companies.

The model is intended to be applied to fiberlines, and where a mill has more than one line, the equations should be applied to each line, and the results summed. To simplify the current project it was applied to each mill as if it had a single fiberline. Ten of the 39 bleached kraft mills discussed in this report have 2 or more bleaching lines. Calculating the costs as if the mill were a single fibreline implicitly assumes an economy of scale that does not exist, so the calculated costs for mills with two fibrelines were increased by 25%, and those with three fibrelines by 50%, to improve the accuracy of the estimate.

The equipment changes required to attain various AOX levels are described below.

2.3.1 Baseline condition

The assumed baseline condition is that a mill would comply with the Federal Regulations regarding discharges of dioxins and furans in the effluent, and also the 1992 Pulp and Paper

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[3] *Detailed data available to the author on US mills suggests that 0.2 to 0.3 GJ/t is a reasonable allowance, assuming that the Canadian industry is operating brown stock systems in a similar fashion to the US.*

2.3.5 Zero AOX by converting to TCF

The term "zero AOX" is widely used, but it is more scientifically correct to describe it as "non-detectable". It normally implies Totally Chlorine Free (TCF) operation. In 1993 the best known TCF technology would have been to extend delignification in the digester with anthraquinone, install an advanced oxygen delignification system, ozone delignification, and convert the former chlorine dioxide bleaching stages to use hydrogen peroxide. Costs herein are based on this technology, although more cost effective processes have since been developed.

This was somewhat risky technology in 1993. The regulators in BC and Ontario who proposed "zero AOX" regulations in 1992/1993 recognized this and set compliance dates in 2002.

2.3.6 Zero AOX while retaining chlorine dioxide

The BFR® process and another proprietary process being developed by EKA-Nobel offer the possibility of eliminating detectable AOX discharges while still using chlorine dioxide, but neither is in full commercial operation at the time of writing, so no attempt was made at estimating the cost of their application in Canada.

2.4 Operating costs

There are a number of impacts on mill operating costs when the process is modified to reduce AOX discharges. Generally, increasing chlorine dioxide substitution and extensive use of hydrogen peroxide increase operating costs, while replacement with oxygen and ozone reduce costs. Mill energy costs are also effected.

2.4.1 Bleaching chemicals

Quantities of bleaching chemicals used vary rather widely from mill to mill, but there was no mill specific information available for preparation of this report. The following costs were assumed for each of the process scenarios. These costs are taken from a study undertaken by McCubbin Consultants for an industrial client in 1994, and were based on then current chemical prices. They are believed to be representative for 1993.

Table 4 Assumed cost of bleaching chemicals ($/ADt pulp)

Bleaching process	AOX	Softwd	Hardwd	Notes
70% substitution to comply with dioxin limit	1.5 kg/t	$53.20	$38.52	Baseline
100% substitution (ECF) without OD	0.8 kg/t	$59.58	$33.25	
Oxygen delignification without ECF	0.8 kg/t	$41.06	$31.65	OD to 15/11 Kappa
ECF with OD and extended cooking (EC)	~0.2 kg/t	$38.73	$31.89	EC to 22/14 Kappa
TCF with ozone and hydrogen peroxide	Zero	$58.83	$48.87	

The costs shown are representative of normal practice and typical Canadian costs in 1993.
Individual mill variations can be +/-40%, or occasionally more.

These costs neglect a number of minor costs and credits, since it is futile to enter into such detail on a country-wide study where mill specific operating data and local costs are not available.

Estimate of AOX control costs for Marbek, July 1997

(Values in parentheses represent reductions in cost)

Company	AOX discharge ========> Location	Production ADt/yr	<0.8 kg/t ECF ECF without OD		<0.8 kg/t Oxy. Delig OD with some chlorine		<0.2 kg/t EC, OD & ECF. Lowest AOX proven in 93		Zero AOX Totally Chlorine Free	
			Capital cost	O & M cost	Capital cost	O & M cost	Capital cost	O & M cost	Capital cost	O & M cost
Cariboo Pulp	Quesnel BC	255,750	$0	$0	$0	$0	$71,608,000	$837,000	$48,067,000	$5,506,000
Celgar	Castlegar BC	400,000	$0	$0	$0	$0	$0	($930,000)	$57,810,000	$8,265,000
CPFP	Gold River BC	230,670	$2,438,000	$1,521,000	$30,924,000	($2,182,000)	$101,217,000	($1,313,000)	$70,628,000	$2,711,000
Crestbrook	Skookumchuck BC	164,010	$2,113,000	$1,089,000	$27,186,000	($1,448,000)	$86,145,000	($650,000)	$61,578,000	$2,155,000
Fletcher Challenge	Campbell River BC	554,000	$4,565,000	$3,628,000	$54,419,000	($5,638,000)	$208,300,000	($3,849,000)	$126,298,000	$5,645,000
Fletcher Challenge	Crofton BC	630,300	$6,080,000	$4,146,000	$71,647,000	($6,220,000)	$301,669,000	($3,085,000)	$166,548,000	$6,879,000
Fletcher Challenge	Mackenzie BC	198,660	$2,288,000	$1,314,000	$29,219,000	($1,828,000)	$94,289,000	($988,000)	$66,501,000	$2,448,000
Howe Sound	Port Mellon BC	455,000	$0	$0	$0	$0	$0	($1,058,000)	$60,973,000	$9,305,000
Macmillan Bloedel	Powell River BC	577,830	$3,728,000	$3,764,000	$44,277,000	($6,130,000)	$158,108,000	($5,197,000)	$102,816,000	$5,309,000
Macmillan Bloedel	Nanaimo BC	343,860	$4,552,000	$2,286,000	$56,349,000	($3,048,000)	$225,825,000	($458,000)	$129,775,000	$4,531,000
Northwood	Prince George BC	441,210	$0	$0	$49,708,000	($7,179,000)	$181,080,000	($5,578,000)	$114,981,000	$1,967,000
Canfor	Prince George BC	484,770	$0	$0	$51,597,000	($7,949,000)	$189,547,000	($6,317,000)	$119,524,000	$2,025,000
Skeena	Prince Rupert BC	394,350	$3,880,000	$2,595,000	$47,559,000	($3,837,000)	$176,660,000	($2,172,000)	$109,803,000	$4,416,000
Western Pulp	Squamish BC	204,600	$0	$0	$29,547,000	($3,199,000)	$93,064,000	($2,405,000)	$67,294,000	$1,192,000
Weyerhaeuser	Kamloops BC	402,930	$0	$0	$47,963,000	($6,505,000)	$173,308,000	($4,935,000)	$110,776,000	$1,912,000
Alpac	Boyle AB	525,000	$0	$0	$0	$0	$0	$123,000	$64,692,000	$10,333,000
Daishowa	Peace River AB	350,000	$0	$0	$0	$0	$0	($814,000)	$54,707,000	$7,314,000
Weyerhaeuser	Grande Prairie AB	240,570	$0	$0	$31,424,000	($3,828,000)	$100,549,000	($3,005,000)	$71,838,000	$1,255,000
Weldwood	Hinton AB	420,000	$0	$0	$0	$0	$0	($977,000)	$58,988,000	$8,644,000
Weyerhaeuser	Prince Albert SK	292,380	$2,706,000	$1,921,000	$33,866,000	($2,873,000)	$113,374,000	($1,962,000)	$77,747,000	$3,201,000
Stone Consolidated	Fort Francis ON	195,000	$2,270,000	$1,290,000	$29,015,000	($1,787,000)	$93,463,000	($952,000)	$66,005,000	$2,418,000
CPFP	Dryden ON	259,000	$0	$0	$32,324,000	($4,152,000)	$104,173,000	($3,317,000)	$74,016,000	$1,285,000
CPFP	Thunder Bay ON	433,000	$0	$0	$49,341,000	($7,035,000)	$179,441,000	($5,440,000)	$114,097,000	$1,955,000
Domtar	Cornwall ON	136,000	$1,961,000	$39,000	$25,353,000	($427,000)	$78,921,000	$676,000	$57,141,000	$2,550,000
E.B. Eddy	Espanola ON	352,400	$0	$0	$0	$0	$105,892,000	$1,298,000	$68,577,000	$7,634,000
James River	Marathon ON	177,000	$2,180,000	$1,174,000	$27,975,000	($1,590,000)	$89,288,000	($775,000)	$63,488,000	$2,266,000
Kimberly Clark	Terrace Bay ON	396,000	$3,888,000	$2,606,000	$47,637,000	($3,855,000)	$177,015,000	($2,189,000)	$109,991,000	$4,429,000
Malette Kraft Pulp	Smooth Rock Falls O	112,200	$0	$0	$0	$0	$46,744,000	$674,000	$34,265,000	$2,679,000
CPFP	La Tuque QC	470,910	$0	$0	$51,007,000	($7,704,000)	$186,893,000	($6,081,000)	$118,104,000	$2,007,000
Domtar	Windsor QC	322,000	$2,827,000	$57,000	$35,155,000	($1,509,000)	$118,771,000	$239,000	$80,861,000	$4,950,000
Domtar	Lebel-Sur-Quevillon	236,940	$2,467,000	$1,562,000	$31,242,000	($2,252,000)	$102,518,000	($1,377,000)	$71,397,000	$2,762,000
Donohue	St. Felicien QC	277,200	$2,643,000	$1,823,000	$33,178,000	($2,702,000)	$110,508,000	($1,800,000)	$76,082,000	$3,082,000
Maclaren Industries	Thurso QC	217,000	$2,375,000	$47,000	$30,214,000	($886,000)	$98,319,000	$527,000	$68,908,000	$3,624,000
Stone Consolidated	Trois Rivières QC	173,910	$2,164,000	$43,000	$27,790,000	($639,000)	$88,551,000	$617,000	$63,041,000	$3,061,000
Stone Consolidated	Portage-du-Fort QC	173,580	$2,163,000	$43,000	$27,771,000	($637,000)	$88,472,000	$618,000	$62,993,000	$3,056,000
Irving	Saint John NB	290,000	$2,697,000	$1,905,000	$33,760,000	($2,846,000)	$112,930,000	($1,937,000)	$77,489,000	$3,182,000
Miramichi	Newcastle NB	241,560	$2,487,000	$1,592,000	$31,473,000	($2,303,000)	$103,467,000	($1,425,000)	$71,957,000	$2,799,000
St. Anne Nackawic	Nackawic NB	199,910	$2,294,000	$46,000	$29,289,000	($787,000)	$94,569,000	$565,000	$66,669,000	$3,402,000
Scott Maritimes	New Glasgow NS	199,980	$2,294,000	$1,323,000	$29,293,000	($1,842,000)	$94,585,000	($1,001,000)	$66,678,000	$2,459,000
	Totals	########	$67,060,000	$35,814,000	$1,177,502,000	($104,817,000)	$4,349,263,000	($65,813,000)	$3,153,103,000	$154,613,000

Costs are expressed in 1993 Canadian dollars, and are based on technology proven 1993, except that the TCF option would have been considered risky in 1993, although it is now proven

Capital cost includes all costs of retrofitting the necessary systems, including recovery system upgrades and increased chlorine dioxide generation capacity where appropriate.

Engineering, construction supervision and similar items often considered as "indirect costs" are included. Land purchase is assumed to be unnecessary

Operating and maintenance costs include chemicals, energy. labour and repairs, but no elements of depreciation, finance costs, or items related to the capital cost.

CAVEAT: Costs are based on generic data for many mills, so individual mill costs may be quite inaccurate.

Data are intended to be used to estimate total costs by Province, or other grouping of several mills.

APPENDIX G

- **Pulp Mill AOX Costs**
  (Based on Simons 1992 Report)

PULP MILL AOX COSTS
(Based on Simons 1992 Report)

A 1992 study by H.A. Simons Consulting Engineers examined several zero AOX scenarios for the BC Ministries of Environment and Economic Development. The study used hypothetical representative mills in place of actual mills.

To adapt the Simons study to generate costs for all Canadian mills, a subjective assessment was used to place each of the kraft mills in Canada into one of the four mill categories presented in Simons (step 1). This assignment was based on the production and pollution characteristics of real mills in 1989 as described in McCubbin's 1992 report for Environment Canada.[1]

Once the mills were classified, the unit cost calculations provided by Simmons were matched to the technology combinations identified in Section 5.1.3 (step 2) and then the total costs were calculated using the production outputs of the applicable mills (step 3).

Step 1 -- Mill Classifications

Not all pulp and paper mills in Canada produce AOX effluent, so the first step to classification was to separate AOX mills from all others. In general, the 39 market kraft and integrated kraft mills operating in 1989 were the AOX producers. Some de-inking and fine paper mills will produce AOX, but their levels are very low (0.1 kg/t) so they were ignored in this analysis.

The characteristics of each of the four hypothetical mills were identified from the Simons report. Readers interested in a detailed description of each mill should refer to the source document. A summary of their characteristics is presented in Table F.1. The goal of the Simons report was to give a representation of the worst and best in the two pulp areas of BC.

Table F.1
Characteristics of Simons' Hypothetical Mills

Mill	Location	Type of Kraft Pulp	Annual Capacity (tonnes)	Primary Treatment	Secondary Treatment	AOX (kg/Adt)	Relative Compliance Costs
A	Interior BC	Market	227,500	Yes	Yes	4.6	High
B	Interior BC	Market	350,000	Yes	Yes	0.9	Low
C	Coastal BC	Semi-bleached integrated and bleached market	280,000	Yes	Just installed	4.6	High
D	Coastal BC	Market	227,500	Yes	Just installed	3.7	Low

Source: H.A. Simons Consulting Engineers, Assessment of Industry Costs to Meet BC's New AOX Regulations, June 1992

[1] McCubbin Consultants, *Economic Impact of Proposed Regulation of Pulp and Paper Industry*, June 1992: Tables A1.9 and A3.4.

Each of the actual Canadian kraft mills was categorized according to how well the mill characteristics matched the four hypothetical mill characteristics. This assessment is, of course, subjective and subject to debate. In general, mills that were deemed to have large environmental challenges were characterized as either type A or C, while relatively cleaner mills were placed in Types B and D. The following guidelines were used to help in the assessment:

- All coastal mills in BC were restricted to Type C and D, just as interior BC mills were restricted to Types A and B. Mills outside BC were usually treated like interior BC mills.
- Mills were classified as Type A and C (high compliance cost) if they exhibited above average compliance costs to the 1991 Federal pulp and paper effluent regulations, lacked primary or secondary treatment facilities, and had higher than average BOD and TSS emissions. Type B and D mills (low compliance cost) had the opposite characteristics.
- Where mills had a mix of characteristics subjective assessments had to be made as to placement.

The results of the classification are presented in Tables F.2 and F.3.

This classification method has drawbacks. Since it is based on costs for mills in BC, using those costs nationwide presumes that a mill in Quebec, for example, would have similar production and pollution profiles as one of the hypothetical mills. For many reasons this may not hold. The wood used in an eastern mill may differ from the fibre available in BC; different provinces have different stumpage fees, tax rates and industrial incentives; the accessibility of timber stands varies geographically; labour rates may differ; and non-governmental environmental groups may exert more or less pressure from region to region—and this is to name but a few distortions. In addition, given the size of some of the compliance costs, it is possible that some of the mills would shut down rather than convert to low AOX or TCF systems. Clearly, a mill by mill assessment of AOX compliance costs would be preferable.

Step 2 -- Unit Cost Estimation

Once the mills are classified, calculation of unit costs is based on the per tonne capital costs and per tonne operating costs of the hypothetical mills. Capital costs were estimated in 1993 dollars. The increments to annual operating costs in each scenario were projected out 20 years and then discounted at 15 percent per year, also to 1993 dollars. Table F.4 outlines the costs estimated for each type of mill in Simons. These costs are over and above the costs associated with meeting the 1991 Federal regulations.

Table F.2
Integrated Kraft Pulp Mills in 1989

Name	Location	Production Tonnes	Amortized Capital & Operating Costs of meeting 1991 BOD TSS regulation per tonne of output	Above (below) Industry Average Compliance Cost of $11.38	Primary Treatment	Secondary Treatment	TSS kg/day	Above (below) Industry TSS Average of 9,936 kg	BOD kg/day	Above (below) Industry BOD Average of 17,318 kg	Correspondence to Simons Hypothetical Mills
Eurocan	Kitimat BC	337,590	$3.00	Below	Yes	Yes	5,524	Below	7,468	Below	D
Fletcher Challenge	Campbell River BC	682,770	$19.94	Above	Yes	No	25,242	Above	52,346	Above	C
Mcmillan Bloedel	Port Alberni BC	427,020	$6.41	Below	Yes	Yes	10,352	Above	9,964	Below	D
Mcmillan Bloedel	Powell River BC	577,830	$16.67	Above	Yes	No	28,016	Above	27,316	Above	C
Fletcher Challenge	Crofton BC	630,300	$18.45	Above	Yes	Yes	19,291	Above	44,885	Above	C
Prince George P&P	Prince Gerarge BC	484,770	$2.19	Below	Yes	Yes	12,340	Above	7,933	Below	B
Manfor	The Pas MN	125,730	$1.06	Below	Yes	Yes	2,629	Below	2,134	Below	B
Boise Cascade	Fort Francis ON	363,000	$2.83	Below	Yes	Yes	4,510	Below	9,680	Below	B
CPFP	Dryden ON	345510	$0.00	Below	Yes	Yes	4,083	Below	2,199	Below	B
CPFP	Thunder Bay ON	814110	$13.47	Above	Yes	No	11,348	Above	44,899	Above	A
Domtar	Red Rock ON	264000	$10.28	Below	Yes	No	4,800	Below	15,920	Below	A
E.B. Eddy	Espanola ON	352400	$0.00	Below	Yes	Yes	5,233	Below	2,136	Below	B
Domtar	Cornwall ON	239910	$28.38	Above	Yes	No	7,052	Below	13,886	Below	A

Name	Location	Production Tonnes	Amortized Capital & Operating Costs of meeting 1991 BOD TSS regulation per tonne of output	Above (below) Industry Average Compliance Cost of $11.38	Primary Treatment	Secondary Treatment	TSS kg/day	Above (below) Industry TSS Average of 9,936 kg	BOD kg/day	Above (below) Industry BOD Average of 17,318 kg	Correspondence to Simons Hypothetical Mills
Stone Consolidated	Trois Rivières QC	173910	$33.21	Above	Yes	No	10,449	Above	13,596	Below	A
CPFP	La Tuque QC	470910	$13.38	Above	Yes	No	11,253	Above	39,376	Above	A
Domtar	Windsor QC	141570	$0.00	Below	Yes	Yes	12,971	Above	18,357	Above	B
Cascades	Jonquiere QC	89760	$30.31	Above	Yes	No	5,287	Below	6,229	Below	A
Cascades	East Angus QO	175,890	$8.55	Below	Yes	No	5,702	Below	4,907	Below	B
Stone Consolidated	New Richmond QC	184800	$8.17	Below	Yes	No	2,705	Below	5,821	Below	B

Sources: McCubbin Consultants, Economic Impact of Proposed Regulation of Pulp and Paper Industry, June 1992; Ontario Ministry of the Environment, Best available Technology for the Ontario Pulp and Paper Industry, a report prepared by McCubbin Consultants, February 1992.

Table F.3
Market Kraft Pulp Mills in 1989

Name	Location	Production Tonnes	Amortized Capital + Operating Costs of meeting 1991 BOD TSS Regulation	Above (below) Industry Average of $10.73	Primary Treatment	Secondary Treatment	TSS kg/day	Above (below) Industry Average of 7,417 kg	BOD kg/day	Above (below) Industry Average of 12,277 kg	Correspondence to Simons
Skeena	Prince Rupert BC	394,350	$30.71	Above	No	No	10,755	Above	34,058	Above	C
CPFP	Gold River BC	230,670	$24.07	Above	Yes	No	6,780	Below	13,770	Above	D
McMillian Blodel	Nanaimo BC	343,860	$13.20	Above	Yes	Yes	9,065	Above	21,986	Above	C
Howe Sound	Port Mellon BC	213,510	$0.00	Below	No	No	6,535	Below	15,657	Above	D
Western Pulp	Squamish BC	204,600	$45.08	Above	Yes	No	10,540	Above	21,452	Above	C
Fletcher Challenge	Mackenzie BC	198,660	$4.14	Below	Yes	Yes	6,201	Below	7,104	Below	B
Northwood	Prince George BC	441,210	$2.18	Below	Yes	Yes	14,841	Above	8,289	Below	B
Cariboo Pulp	Quesnel BC	255,750	$2.40	Below	Yes	Yes	9,765	Above	3,952	Below	B
Weyrhaurser	Kamloops BC	402,930	$1.24	Below	Yes	Yes	12,943	Above	2,808	Below	B
Celgar	Castlegar BC	181,500	$24.77	Above	Yes	No	7,865	Above	32,065	Above	A
Crestbrook	Skookumchuck BC	164,010	$0.00	Below	Yes	Yes	3,280	Below	2,584	Below	B
P&G	Grande Prairie AB	240,570	$4.10	Below	Yes	Yes	3,353	Below	5,167	Below	A
Weldwood	Hinton AB	177,870	$0.00	Below	Yes	Yes	9,379	Above	3,935	Below	A
Weyerhauser	Prince Albert SK	292,380	$3.27	Below	Yes	Yes	12,050	Above	4,696	Below	A
Kimberly Clark	Terrace Bay ON	396,000	$0.00	Below	Yes	Yes	5,520	Below	2,484	Below	A
James River	Marathon ON	142,890	$15.15	Above	Yes	No	2,641	Below	13,553	Above	B
Malette Kraft Pulp	Smooth Rock Falls ON	112,200	$17.87	Above	Yes	No	4,760	Below	7,888	Below	B

Name	Location	Production Tonnes	Amortized Capital + Operating Costs of meeting 1991 BOD TSS Regulation	Above (below) Industry Average of $10.73	Primary Treatment	Secondary Treatment	TSS kg/day	Above (below) Industry Average of 7,417 kg	BOD kg/day	Above (below) Industry Average of 12,277 kg	Correspondence to Simons
Domtar	Lebel-Sur-Quevillon QC	236,940	$16.22	Above	Yes	No	5,480	Below	25,427	Above	B
Stone Consolidated	Portage-du-Fort QC	173,580	$2.73	Below	Yes	Yes	3,709	Below	5,291	Below	A
Maclaren Industries	Thurso QC	120,780	$15.04	Above	Yes	No	4,242	Below	13,835	Above	A
Donohue	St. Felicien QC	277,200	$2.52	Below	Yes	Yes	8,113	Above	6,170	Below	B
St. Anne Nackawic	Nackawic NB	199,910	$0.00	Below	Yes	Yes	4,054	Below	3,206	Below	B
Irving	Saint John NB	239,910	$32.05	Above	No	No	8,651	Above	17,593	Above	A
Miramichi	Newcastle NB	241,560	$4.10	Below	Yes	Yes	10,907	Above	6,808	Below	B
Scott Maritime	New Glasgow NS	199,980	$5.25	Below	Yes	Yes	4,000	Below	4,787	Below	A

Sources: McCubbin Consultants, Economic Impact of Proposed Regulation of Pulp and Paper Industry, June 1992; Ontario Ministry of the Environment, Best available Technology for the Ontario Pulp and Paper Industry, a report prepared by McCubbin Consultants, February 1992.

In order to match the Simons estimates to the technology combinations (and their associated regulatory objectives), the following assumptions were made:

- ***1.5 kg/t.*** This would require 90 percent or greater chlorine dioxide substitution for chlorine gas in the bleaching process in all mills. In addition, oxygen delignification would be necessary to consistently meet the target in type A, C and D mills.

- ***0.8 kg/t.*** To meet this level, Simons found that, in addition to full ClO_2 substitution, type A, C and D mills required extended cooking in the mills' existing digester plants, with oxygen delignification and possible expansion of recovery boiler capacity. Simons also found that type B mills would attain 0.9 kg/t AOX with full substitution. However, estimates prepared by McCubbin for the Ontario Ministry of the Environment suggests that full substitution would yield AOX effluents below 0.8 kg/t in Ontario's mills.[2] For the purposes of this analysis, we have assumed that type B mills could meet a 0.8 kg/t limit with 100% ClO_2 substitution only (a conservative assumption for the purpose of calculating cost savings).

- ***<0.8 kg/t.*** This limit is associated with the use of the best available technology to reduce AOX emissions while continuing to use ClO_2. Estimates prepared by McCubbin for the Ontario Ministry of the Environment suggests that the best available technology would yield AOX effluents between 0 and 0.31 kg/t in Ontario's mills.[3] Simons estimates are in the range of 0 to 0.5 kg/t. The calculations are based on use of the same technology by all mills, while recognizing that some mills would perform better than others.

- ***Zero AOX.*** This scenario is based on a complete elimination of AOX and the production of TCF pulp. To do this, mills would have to replace their digester plants and go to ozone bleaching. None of the existing chlorine based bleaching equipment could be converted to handle ozone so a TCF process would require a new bleaching stage and an ozone bleach generator. This would apply to all mill types.

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[2] Ontario Ministry of the Environment, Best available Technology for the Ontario Pulp and Paper Industry, a report prepared by McCubbin Consultants, February 1992, p 262.

[3] Ibid.

Table F.4
Costs per Tonne of Output (Cumulative) for the Hypothetical Mill Types ($1993)

Mill Types	Cost Type	AOX Regulations (Kg/t)			
		1.5	0.8	<0.8	0
Type A	Annual Operating Costs	16	16	52	153
	Net Present Value of Operating Costs	100	100	325	958
	Capital Compliance Cost	330	330	440	809
	Total Amortized Costs	430	430	765	1767
Type B	Annual Operating Costs	0	0	28	106
	Net Present Value of Operating Costs	0	0	175	663
	Capital Compliance Cost	0	0	231	326
	Total Amortized Costs	0	0	406	989
Type C	Annual Operating Costs	7	121	121	163
	Net Present Value of Operating Costs	44	757	757	1020
	Capital Compliance Cost	364	929	929	1011
	Total Amortized Costs	408	1686	1686	2031
Type D	Annual Operating Costs	6	49	49	155
	Net Present Value of Operating Costs	38	307	307	970
	Capital Compliance Cost	338	440	440	809
	Total Amortized Costs	376	747	747	1679

Step 3 -- Calculation of Total Costs

The final step in the calculations is to combine the estimated unit costs with the actual production of the mills across Canada. For each regulatory possibility, the capital and operating costs per tonne for the four hypothetical mill categories were multiplied by the outputs of the actual mills placed in each category. This gave individual mill compliance cost estimates. The total compliance costs on a national and regional basis were obtained by adding the appropriate individual estimates.

The results are presented in Tables F.5 to F.8.

Table F.5
1.5 kg/t AOX Net Compliance Costs ($ million 1993)

Region	Mill Type	Net Capital	Net Amortized Operating	Total
BC	A	60	18	78
	B	0	0	NA
	C	1,032	124	1,156
	D	399	45	444
	All Mills	1,491	188	1,678
Alberta	A	138	42	180
	All mills	138	42	180
Prairie	A	96	29	126
	B	0	0	0
	All Mills	96	29	126
Ontario	A	565	172	737
	B	0	0	0
	All Mills	565	172	737
Quebec	A	339	103	442
	B	0	0	0
	All Mills	339	103	442
Atlantic	A	145	44	189
	B	0	0	0
	All Mills	145	44	189
Total	A	1,206	366	1,572
	B	0	0	0
	C	1,032	124	1,156
	D	399	45	444
	All Mills	2,636	536	3,172

Table F.6
0.8 kg/t AOX Net Compliance Costs ($ million 1993)

Region	Mill Type	Net Capital	Net Amortized Operating	Total
BC	A	60	18	78
	B	0	0	0
	C	2,631	2,146	4,777
	D	531	371	902
	All Mills	3,222	2,535	5,758
Alberta	A	138	42	180
	All Mills	138	42	180
Prairie	A	96	30	126
	B	0	0	0
	All Mills	96	30	126
Ontario	A	565	172	737
	B	0	0	0
	All Mills	565	172	737
Quebec	A	339	103	442
	B	0	0	0
	All Mills	339	103	442
Atlantic	A	145	44	189
	B	0	0	0
	All Mills	145	44	189
Total	A	1,343	409	1,752
	B	0	0	0
	C	2,631	2,146	4,777
	D	531	371	902
	All Mills	4,506	2,926	7,432

Table F.7
<0.8 kg/t AOX Net Compliance Costs ($ million 1993)

Region	Mill Type	Net Capital	Net Amortized Operating	Total
BC	A	80	59	139
	B	451	341	792
	C	2,631	2,146	4,777
	D	531	371	902
	All Mills	3,693	2,917	6,610
Alberta	A	184	136	320
	All Mills	184	136	320
Prairie	A	129	95	224
	B	29	22	51
	All Mills	158	117	275
Ontario	A	753	558	1,311
	B	305	231	535
	All Mills	1,058	789	1,847
Quebec	A	452	335	787
	B	235	178	413
	All Mills	688	513	1,201
Atlantic	A	193	143	337
	B	102	77	180
	All Mills	296	221	516
Total	A	1,607	1,190	2,798
	B	1,122	849	1,971
	C	2,631	2,146	4,777
	D	531	371	902
	All Mills	5,892	4,557	10,448

Table F.8
Zero AOX Net Compliance Costs ($ million 1993)

Region	Mill Type	Net Capital	Net Amortized Operating	Total
BC	A	147	174	321
	B	634	1,292	1,926
	C	2,864	2,891	5,755
	D	978	1,173	2,150
	All Mills	4,623	5,530	10,153
Alberta	A	338	401	739
	All Mills	338	401	739
Prairie	A	236	280	516
	B	41	83	124
	All Mills	277	363	641
Ontario	A	1,386	1,641	3,028
	B	429	873	1,302
	All Mills	1,815	2,515	4,330
Quebec	A	832	985	1,818
	B	331	674	1,005
	All Mills	1,163	1,660	2,823
Atlantic	A	356	421	777
	B	144	293	437
	All Mills	500	714	1,214
Total	A	3,296	3,903	7,199
	B	1,579	3,216	4,795
	C	2,864	2,891	5,755
	D	978	1,173	2,150
	All Mills	8,716	11,183	19,899

APPENDIX H

Details of Calculations of German TCF Market Share - Base Case

DETAILS OF CALCULATIONS OF GERMAN TCF MARKET SHARE - BASE CASE

German consumption of market pulp in tonnes was obtained from (among other sources) the United States Department of Commerce. Assuming that market share of TCF in Germany was currently (1996) 30% (source: Richard Cockram), we calculated the 1996 consumption of TCF pulp and ECF+conventional pulp (Table H.1).

Table H.1
German bleached Market Pulp consumption - tonnes ('000)

Type	1990	1991	1992	1993	1994	1995	1996
Total	3,578,259	4,088,439	3,972,287	3,611,290	3,955,067	4,027,795	3,482,576
TCF							1,044,773
ECF+ Conventional							2,437,803

To fill in the years 1990-95, we relied on the one year of data available (1996) and the only time series on TCF pulp available--that published by AET (Trends in World Bleached Chemical Pulp Production, 1990-1997). Unfortunately, the AET document gives total TCF production--that is both ***market*** and ***integrated*** TCF pulp. To get from the *market and integrated* TCF production figures for the world to just German TCF *market* pulp consumption the following steps were taken:

- We divided the 1996 German TCF market pulp consumption value of 1.04 million tonnes (as estimated above), by the 1996 TCF world market and integrated production value of 4.5 million tonnes and arrived at a figure of 23% of world TCF production sold as market pulp in Germany in 1996.

- Assuming that this share was constant through the 1990s, we multiplied the rest of the AET TCF pulp time series by 23% to give the estimated values of German TCF market pulp consumption for 1990 to 1996.

- ECF+conventional pulp in Germany was calculated as a residual using Germany's actual bleached market pulp consumption

- The market share was calculated by dividing the result by the total consumption.

The results are provided in Table H.2

Table H.2
German bleached Market Pulp Consumption by Type

	1990	1991	1992	1993	1994	1995	1996
World TCF market and integrated pulp Tonnes ('000)	100,000	400,000	1,200,000	2,600,000	4,100,000	4,700,000	4,500,000
Multiplied by	23%	23%	23%	23%	23%	23%	NA
= German TCF market pulp Consumption (A) Tonnes ('000)	23,217	92,869	278,606	603,647	951,904	1,091,207	1,044,773
Total German Market consumption (B)	3,578,259	4,088,439	3,972,287	3,611,290	3,955,067	4,027,795	3,482,576
(B) Less (A) = German ECF+ conventional market pulp consumption Tonnes ('000)	3,555,042	3,995,571	3,693,681	3,007,644	3,003,163	2,936,588	2,437,803
TCF Market Share	0.65%	2.27%	7.01%	16.72%	24.07%	27.09%	30.00%
ECF Market Share	99.35%	97.73%	92.99%	83.28%	75.93%	72.91%	70.00%

APPENDIX I

Estimation of Social and Economic Impacts Using Input-Output Model of Canada

ESTIMATION OF SOCIAL AND ECONOMIC IMPACTS USING INPUT-OUTPUT MODEL OF CANADA

Input-output tables show the interrelation of different components of the economy. Each industry buys inputs (raw materials, labour, machinery, equipment, and services) in order to make outputs. An input matrix shows what is used to make an industry's final products — it is expressed in terms of the dollar value of the commodities that are purchased by an industry. An output matrix shows what is produced by an industry — it is expressed in terms of the dollar value of the final commodities that are produced by an industry. Other matrices in the input-output tables give the value of the final demand by broad consumption categories for each commodity and a relationship between inputs and outputs with employment levels.

Using the structure of the input-output tables it is possible to isolate an individual industry or commodity for the purpose of analyzing its impact on the whole economy. This is done by simulating a revenue "shock" to the industry or a demand shock to the corresponding commodity. Typically this shock would be characterized by a hypothetical increase (or decrease) in the value of the industry's output by a given amount or by a hypothetical increase (or decrease) in the sales of a commodity. The impact of a $10 million loss in sales of the commodity wood pulp would produce a shock that tells us:

- What would happen to the sale of other commodities that are used in the production of the $10 million of pulp.
- Which industries would have produced these inputs and what was the size of their lost sales.

Social and Economic Impacts of Markets Preserved as a Result of NWRI

To estimate the economic impact of the markets that were preserved, the value of those markets was expressed as a vector of commodity sales, which was then run through the input-output model to calculate direct and indirect impacts on output, GDP, and employment.

Over the period 1993 to 1996, Canada had chemical wood pulp exports to western Europe which totalled over $6.4 billion. These exports can be divided into distinct commodity types as outlined in Table I.1.

Table I.1
Exports 1993 to 1996 to Europe
Thousands of dollars

Type of bleached chemical wood pulp	HS Code	Value 93-96	% distribution
Soda or sulphate, coniferous	4703.21	5,125,795	80%
Soda or sulphate, non-coniferous	4703.29	988,235	15%
Sulphite, coniferous	4704.21	301,586	5%
Sulphite, non-coniferous	4704.29	3,771	0.1%
Total Chemical Wood Pulp		6,419,387	100%

Ordinarily, when using the input-output tables a detailed distribution of the shocks is desirable. This gives the most realistic break-down of impacts. However, in this case we have more detail than the model is capable of handling so we must settle for the aggregate commodity, chemical wood pulp, as the only commodity distributed in our initial shock to the model.[1]

Given these assumptions, Statistics Canada provided the following results for each $1,000,000 in sales:

- A contribution to GDP of $744,000 in 1993 dollars
- A demand for labour equal to 11.9 person years of employment

The GDP effect breaks down as follows:

- 533,000 in labour income (71.6%)
- 211,000 in business income (28.4%).

The following tables (I.2 and I.3) break these results down by industry.

Table I.2
GDP by Industry (per $million in sales)

Industry	GDP ($1993)	Percent
Paper & Allied Products Industries	$238,312	32.01%
Transportation Industries	$79,084	10.62%
Logging & Forestry Industries	$72,594	9.75%
Other Utility Industries	$59,409	7.98%
Wholesale Trade Industries	$51,706	6.95%
Wood Industries	$40,564	5.45%
Chemical & Chemical Products Ind.	$25,350	3.41%
Finance & Real Estate Industries	$20,516	2.76%
Business Service Industries	$20,160	2.71%
Govt. Royalties On Nat. Resources	$20,011	2.69%
Total Top Ten	$627,706	84.31%
Total All Industries	$744,479	

[1] The input output model specifies over 600 different types of commodities, though this is extensive it leaves many commodities aggregated into larger groups.

Table I.3
Employment by Industry (person years of employment per $million in sales)

	Direct	Indirect	Total	Percent
Paper & Allied Products Industries	3.5	0.1	3.6	30.37%
Transportation Industries	0.5	1.0	1.5	12.21%
Logging & Forestry Industries	0.0	1.1	1.1	9.40%
Wholesale Trade Industries	0.2	0.8	1.0	8.74%
Wood Industries	0.0	0.8	0.8	6.94%
Retail Trade Industries	0.0	0.6	0.6	5.19%
Other Service Industries	0.0	0.5	0.5	4.63%
Business Service Industries	0.0	0.5	0.5	4.04%
Other Utility Industries	0.0	0.3	0.3	2.51%
Finance & Real Estate Industries	0.0	0.3	0.3	2.26%
Total Top Ten	4.2	6.1	10.2	86.29%
Total all Industries	4.2	7.7	11.9	100.00%

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