July 1996 Floods in Quebec: Identification of Potential Impacts on the Marine Environment and Freshwater Habitats in the Saguenay, North Shore, and Charlevoix Regions

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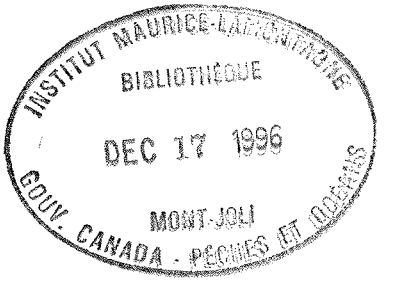

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This report provides an assessment of the potential impacts of the July 1996 floods on the marine environment and freshwater habitats in the Saguenay, North Shore and Charlevoix regions. Overall, the most impacted sectors are situated in Ha! Ha! Bay and on the various waterways in the Saguenay area. On the North Shore and in the Charlevoix region, damage to the marine environment and freshwater habitats was less severe and less widespread. The main impacts observed on the tributaries of the Saguenay consist in severe erosion of the riverbanks and riverbed, along with a mass flushing of fish species downriver. The alterations observed in the marine environment are attributable to the influx of sediments and assorted debris that were deposited on the sea bed. These deposits likely had considerable effects on benthic fauna and aquatic weedbeds, resulting in a loss of spawning and feeding habitats for several species. Based on new information collected by the Department of Fisheries and Oceans (DFO) and other scientific organizations, DFO's Science Sector plans to continue its evaluation work concerning the impacts of the floods and, as required, will recommend future action appropriate for the follow-up of the state of the marine environment, fishery resources, and use of the Saguenay marine environment.

RÉSUMÉ

Walsh, G. and A. Bourgeois (editors). 1996. July 1996 Floods in Quebec: Identification of Potential Impacts on the Marine Environment and Freshwater Habitats in the Saguenay, North Shore, and Charlevoix Regions. Can. Manuscr. Rep. Fish. Aquat. Sci. 2382: vii + 20 p.

Ce rapport présente une évaluation des impacts potentiels des inondations de juillet 1996 sur le milieu marin et sur les habitats d'eau douce au Saguenay, sur la Côte-Nord et dans Charlevoix. De façon globale, les secteurs qui ont été les plus touchés se situent dans la baie des Ha! Ha! et dans les divers cours d'eau de la région du Saguenay. Sur la Côte-Nord et dans Charlevoix, les dommages causés au milieu marin et aux habitats d'eau douce ont été moins sévères et moins nombreux. Les principaux impacts rencontrés dans les rivières tributaires du Saguenay sont liés à une érosion importante de leurs rives et de leur lit ainsi qu'à une dévalaison massive des espèces de poissons. Les modifications rencontrées dans le milieu marin sont attribuables à un apport de sédiments et de débris de toutes sortes qui se sont déposés sur les fonds marins. Ces accumulations ont probablement eu des effets considérables sur la faune benthique et sur les herbiers aquatiques. Il en résulte une perte d'habitats pour la reproduction et l'alimentation de plusieurs espèces utilisatrices de ces milieux. Sur la base de nouvelles informations qui seront recueillies par le ministère des Pêches et des Océans (MPO) et d'autres organisations scientifiques, le secteur des Sciences du MPO poursuivra son travail d'évaluation des impacts des inondations et, le cas échéant, recommandera les mesures requises pour effectuer un suivi de l'état du milieu marin, des ressources halieutiques et des usages du milieu marin du Saguenay.

EXTENDED SUMMARY

This document presents an evaluation of the potential impacts of the July 1996 floods on the marine environment and freshwater habitats in the Saguenay, North Shore and Charlevoix regions. Since this evaluation is based on information that is for the time being incomplete, it should be considered preliminary.

The hardest hit sectors are located in Ha! Ha! Bay and at the mouth of tributaries that empty into the Saguenay. In these areas, tremendous quantities of particulate matter from erosion in drainage basins and riverbanks were deposited on the seabed. Reports indicate that a sediment layer 30 cm thick was deposited in the middle of Ha! Ha! Bay, and a 10 cm layer was deposited on the upper slope of the inner basin of the Saguenay Fjord. Elsewhere in the fjord, the sediment input appears to be comparable to normal levels of accumulation.

Potentially toxic substances were carried by the flood waters into the marine environment of Ha! Ha! Bay and the Saguenay Fjord. Based on preliminary data, the quantities appear small in relation to the capacity of the receiving environment. Sediment inputs from drainage basins can likely be considered as relatively contaminant-free.

Because of their mobility, fisheries resources such as fish and crustaceans probably were not directly affected by these events. However, the complete or partial disappearance of bulrush beds and saltmarsh communities represents a loss of feeding, reproduction, or nursery habitat for many species. Ice fishing could also be impacted by the July floods, although it is difficult to accurately predict effects of this type.

Sediment deposits resulting from the floods have likely had important effects on benthic organisms of Ha! Ha! Bay and the slope of the inner basin of the fjord. The effects will nonetheless be temporary, given the ability of benthic organisms to rapidly recolonize a disturbed environment. Aquatic weedbeds in Ha! Ha! Bay were also impacted by sediment deposits.

In many of the Saguenay's tributaries, fish habitats have been profoundly altered owing to major changes to the riverbed. River flow pattern and particle size composition have been greatly modified over variable distances, in some cases as far as 10 kilometres. Fishing data indicate that a sharp decline occurred in fish populations during high water, especially the early life stages (fry and juveniles). On a longer term basis, the species that frequent these waterways could be affected by the modification or potential loss of spawning and feeding habitats.

On the North Shore and in the Charlevoix region, damage to the marine environment and freshwater habitats was less severe and less widespread than in the Saguenay. Landslides and bank erosion have been reported in localized areas along the rivers. The riverbeds might become clogged with fine particles as a result of this, possibly impairing spawning grounds. The freshet and the floods are believed to have had little or no direct effect on the marine environment of the St Lawrence.

This document describes various measures which could be undertaken to assess the impacts of the floods in more detail, to ensure navigational safety, to monitor sport fishing, and to ensure the safety of fishery products. It also gives an overview of the reconstruction and recovery projects that may require environmental assessment.

CONTRIBUTORS

The following people, listed in alphabetical order, contributed to the preparation of this document: Luci Bossé, Marie-France Dalcourt, Patrick Dupont, Michel Gilbert, Charles Gobeil, Michèle Grenier, Denis Hains, Daniel Hardy, Michel Harvey, Jean-Denis Lambert, Judith Leblanc, Jean Morisset, Jean Munro, Lucie Pagé, Jean Piuze, and Bernard Sainte-Marie.

1. INTRODUCTION

The summer of 1996 will be long remembered for the extraordinary hydrological events that occurred in Quebec. In the middle of July, torrential rainfall caused exceptionally high water conditions in the Saguenay, North Shore and Charlevoix regions (Figure 1). A number of rivers overflowed their banks or left their channels, causing floods in many areas. The Saguenay region was particularly affected; water in many rivers reached record high levels (Quebec Department of the Environment and Wildlife [Ministère de l'Environnement et de la Faune, MEF], pers. comm.).

In addition to causing considerable material damage in these regions, these events likely had effects on the marine environment and freshwater habitats. In keeping with its mandate, which includes providing the federal government with scientific advice on conserving marine fishery resources, protecting the marine environment and fish habitats, and establishing rules for safe navigation, the Science Sector of the Department of Fisheries and Oceans (DFO) is responsible for

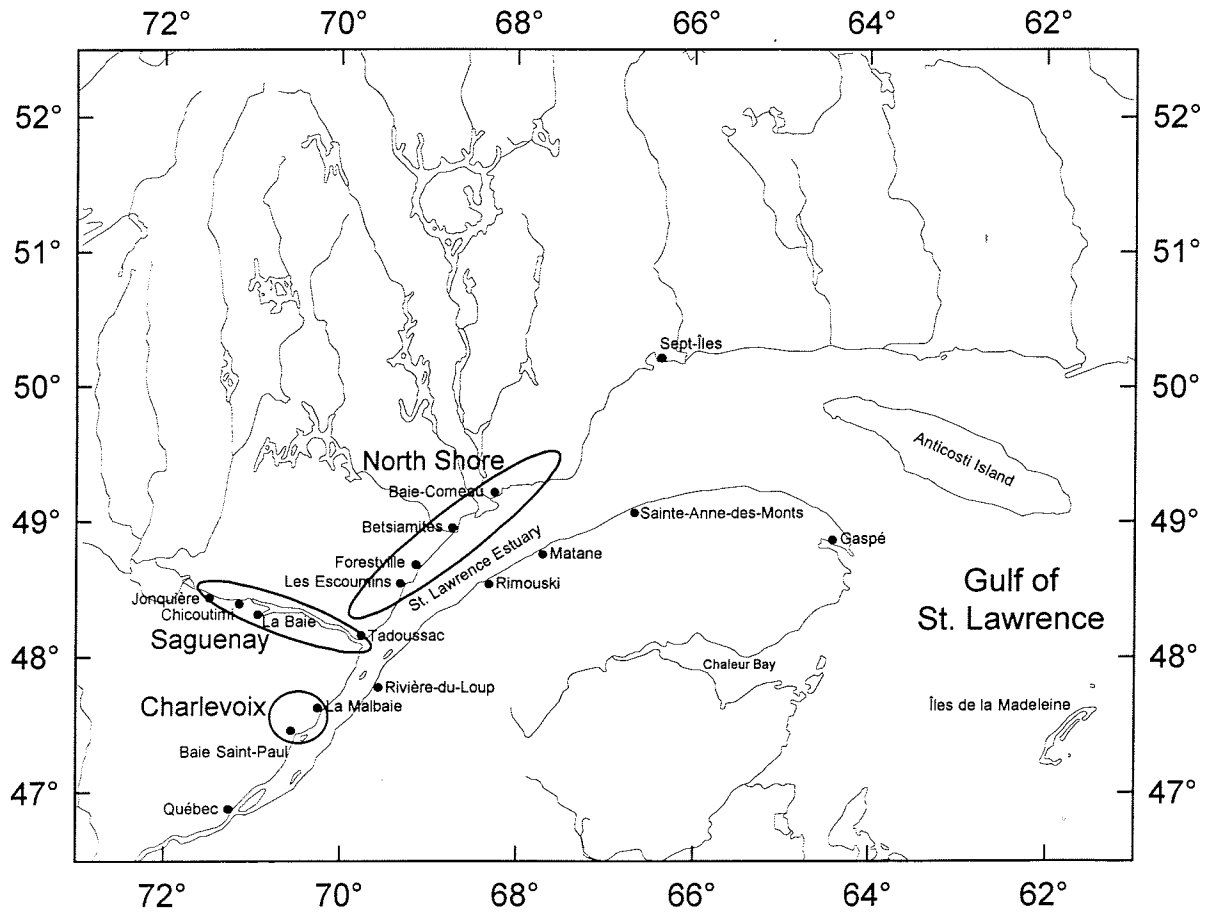

Figure 1. Location of zones affected by the July 1996 floods in the Saguenay, North Shore and Charlevoix regions.

assessing the present state of affairs in the Saguenay region, along the banks of the St Lawrence River, in the North Shore and Charlevoix regions, and in their tributaries.

In this context, this report provides a preliminary portrait of the potential effects of the July 1996 floods on the different components of the marine environment and on fish habitat. More specifically, the purpose of the document is to:

- Provide an overview of the effects of the floods on the bathymetry of navigational zones;
- Furnish an initial scientific assessment of the potential effects on water quality (physico-chemical characteristics), benthic fauna, fishery resources, and ice fishing;
- Provide advice on possible contamination of the environment by toxic substances that may have been released during the flooding;
- Evaluate the damage to fish habitats in riverine and marine environments; and
- List the reconstruction projects and other work in aquatic environments that might necessitate an environmental assessment.

This document is the results from the collaboration of several DFO experts and is also based on consultations with regional branches of the MEF. However, since it is based on incomplete data, it should be considered preliminary. In addition, the document indicates what additional scientific information is needed to better determine the impacts on the marine environment and freshwater habitats.

For more details on habitats, fauna, and marine environment use in the area, readers can refer to Gagnon (1995) and to Mousseau and Armellin (1995).

2. SUMMARY OF EVENTS AND GEOGRAPHIC SETTING

Between July 19 and 21, Environment Canada (EC) reports that some 125 to 200 mm of rain fell on various localities along the Saguenay River and Fjord along with 100 to 150 mm and 75 to 125 mm on the Upper North Shore (between Tadoussac and Baie-Comeau) and in the Charlevoix region. However, the heaviest rainfall was recorded by the MEF on the Écorces River, a tributary of Lake Kénogami, which received a record 279 mm. This rain caused a sudden freshet in many waterways, several of which overflowed and flooded the surrounding area, resulting in considerable damage.

The Saguenay area was the hardest hit, with river flow there exceeding all previously recorded values. To illustrate the magnitude of this event, the flows of the Chicoutimi and Sables rivers reached 1200 m^3/s and 660 m^3/s compared with historic maxima of 631 and 214 m^3/s respectively. The annual mean flow of the two rivers is estimated at 68 m^3/s and 42.5 m^3/s.

Not only did flooding occur, but flow velocity also increased due to the steep slope of the terrain, thereby severely eroding the banks and considerably the river beds. Tremendous quantities of sediment were transported by the high waters toward the mouth of the rivers and the Saguenay Fjord. As well, countless tree trunks and assorted debris were carried off by the waters as they swept through and destroyed forests and infrastructures along the waterways (bridges, roads, houses, businesses, factories, farms, etc.). In addition, various chemical substances were probably mixed in with this flow, some of which could be potentially toxic.

In the North Shore and Charlevoix regions, the flooding was not as serious and damage was much less extensive. Flow data are not yet available for the rivers in these two regions, but based on the preliminary assessment by local MEF biologists, the July flooding was for the most part comparable to a large spring freshet, except on a few rivers, where it was slightly greater (Escoumins and Sault-aux-Cochons rivers). Landslides and riverbank erosion were observed in a few areas.

The Upper Mauricie sector also experienced major flooding last July 1996. Culverts along several forest roads were washed out, and extensive damage to riverbanks was reported, especially on the Croche River, a tributary of the Saint-Maurice River. However, few major impacts were reported with respect to fish habitat in the region (MEF–Shawinigan). Consequently, it has been suggested that more in-depth investigation is not required there.

For the purposes of this document, the study area is the marine environment of the Saguenay Fjord, between Tadoussac and Saint-Fulgence (Figure 2). However, with respect to fish habitat, the study area encompasses the majority of the waterways in the three regions that sustained damage during the heavy July rains, that is, the Saguenay, North Shore, and Charlevoix areas.

3. PRELIMINARY IMPACT IDENTIFICATION

3.1. SEDIMENTS

An oceanographic cruise led by McGill University was carried out aboard the vessel *Alcide C. Horth* from August 18 to 25, 1996, approximately one month after the floods (Mucci 1996). Based on preliminary observations, the area of the Saguenay Fjord affected by the floods can be delineated in a summary fashion. During the cruise, sediment samples were collected at six stations scattered over the inner basin of the fjord (Figure 2), using a grab sampler, a box corer, and a multiple tube core sampler.

The samples collected show that the sedimentation processes following the floods occurred primarily in Ha! Ha! Bay and in the upstream slope of the fjord's inner basin (Table 1). The samples from these areas show sediment accumulations ranging from 5-10 cm in thickness on the slope of the inner basin and up to 30 cm in the middle of Ha! Ha! Bay. However, the sediment accumulations in the deepest part of the inner basin and farther downstream were only a few millimetres at most, which is on the same order as the annual mean accumulation (2-4 mm) of sediment in this zone (Schafer *et al.* 1990).

The samples also showed that the new sediment layer consisted mainly of fine particles and could be distinguished from underlying sediments by its more greyish colour, higher porosity, and absence of benthic organisms.

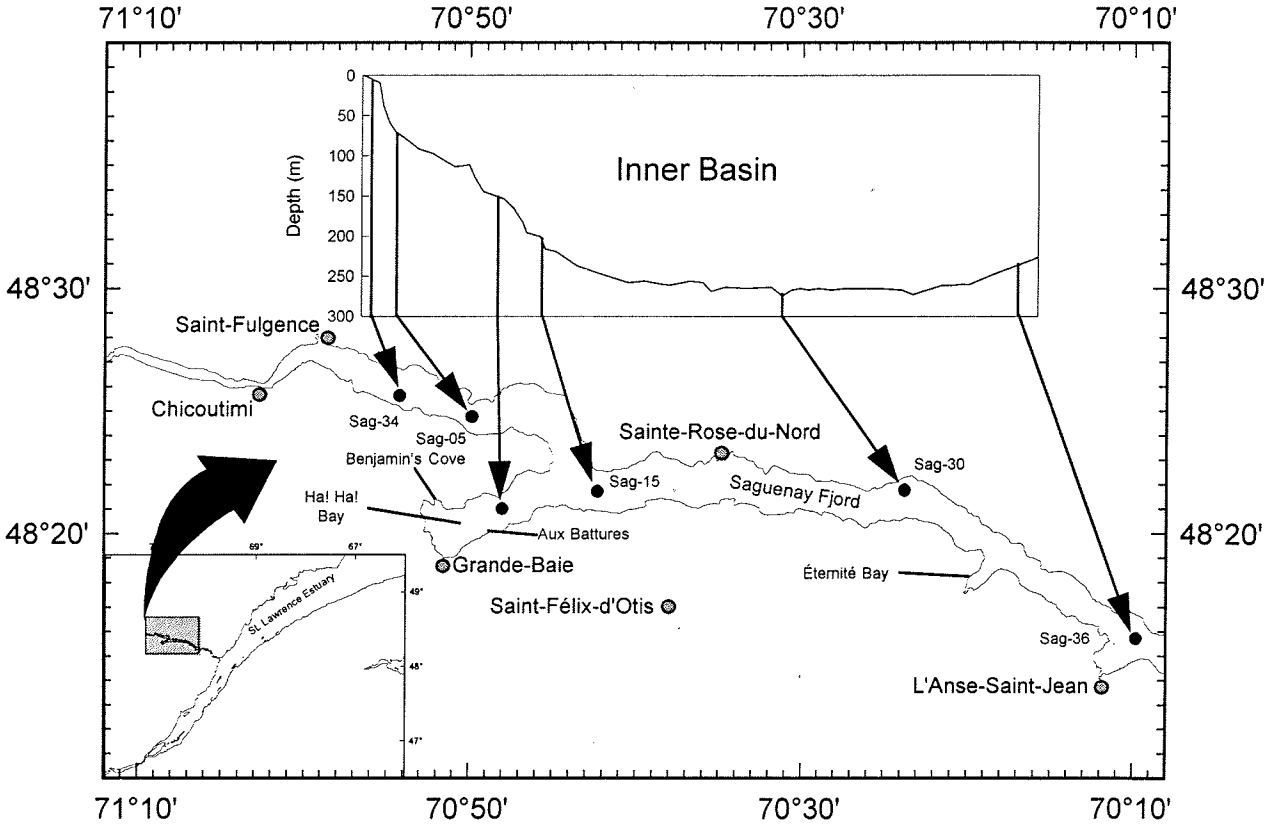

Figure 2. Cartography and bathymetry of the upstream part of the Saguenay Fjord, showing the stations where sediments were sampled during the scientific cruise of the *Alcide C. Horth* between August 18 and 25, 1996.

Table 1. Thickness of the sediment layer deposited in the inner basin of the Saguenay Fjord and in Ha! Ha! Bay as a direct result of the floods of July 19-20, 1996.

Station	Depth (m)	Thickness of deposit (cm)
Sag-34	14	5 - 10
Sag-05	65	5 - 10
Sag- Ha! Ha! Bay	150	~ 30
Sag-15	210	5 - 10
Sag-30	270	< 0.5
Sag-36	234	< 0.5

The positions of the stations are shown in Figure 2 (Source: Gobeil 1996).

3.2. BATHYMETRY

In general, sediment inputs have little impact on water depth in the Saguenay Fjord, given the considerable depths involved. However, shallow sites, notably near port facilities and in Ha! Ha! Bay, may have been modified substantially, with potential repercussions on navigation and on fishery resource exploitation. The intensity of these impacts vary depending on the quantity of sediment deposited relative to the original water depth.

3.3. PHYSICO-CHEMICAL CHARACTERISTICS

During the scientific cruise of August 18 to 25, 1996 in the Saguenay Fjord, temperature, salinity, and turbidity profiles were also conducted at the stations shown in Figure 2. The results do not show any anomalies in these parameters compared with previous observations (Schafer *et al.* 1990). Turbidity appeared to be normal based on the many water samples taken during the cruise. Profiles for determining oxygen levels were made as well; as with the other parameters, these values seemed normal one month after the floods.

3.4. CONTAMINATION

Preliminary information from a chemical substance inventory prepared by the MEF indicates that a few propane tanks, the gasoline reservoirs from a service station, and some transformers containing PCB-laced oil (less than 50 ppm) along with about 50 gallons of transformer oil were swept away by the flood. In addition, overflow waters from waste treatment ponds or systems and leachate from landfill sites entered and may still be flowing into the environment. In addition to these substances, an unknown and uninventoried quantity of toxic substances stocked by merchants and individuals was no doubt also carried off by the flood waters.

A number of the compounds thus released could contaminate the environment and living organisms living there. However, in view of the vast size of the receiving environment, the small quantities involved, and the fact that many contaminants were stored in water-tight containers, it is unlikely that these inputs had major impacts on organisms in the marine environment of the Saguenay.

Drainage basin sediments carried by the flood waters and deposited on the seabed can be considered relatively contaminant-free. The new, relatively clean sediment layer laid down on the bottom of Ha! Ha! Bay can be regarded as beneficial since it would bury sediment already contaminated with substances such as mercury, thereby making the contaminants less available to the food chain.

It should be noted that, during a September 1996 scientific cruise, led by UQAR (University of Quebec at Rimouski) and INRS–Océanologie, at Rimouski, scientists observed the presence of traces of hydrocarbons in sediments sampled at the most upstream stations in Ha! Ha! Bay. Until the sediment samples are analyzed, it will not be possible to determine whether these hydrocarbons were carried to these sites by the flood waters or whether they were there previously (É. Pelletier, INRS–Océanologie, comm. pers.).

3.5. BENTHIC FAUNA

The composition of benthic fauna is closely linked to the nature of the substrate. The July floods increased the sediment load in the water column. Sediments settle on bottom areas over variable time periods, altering normal conditions (Schafer *et al.* 1990). A high sedimentation rate might disturb and modify the existing benthic communities. In an extreme situation like a landslide, where the change is sudden and extensive, the benthic fauna in the affected zone can be completely altered. While some species disappear, others gradually recolonize the area (Desrosiers *et al.* 1984).

The north arm of the Saguenay Fjord, Ha! Ha! Bay, and the slope of the inner basin of the fjord are characterized by low plankton production and low benthic biomass. In these areas, the density of suspended matter and the deposition rate are fairly high compared to the downstream sector of the fjord; oxygen levels are sometimes limiting in the characteristic muddy bottoms there. The particular input consists of sand, silt, clay and organic matter of various proportions depending on the current velocities in upstream rivers. These inputs are particularly large during spring freshets. During the 20th century, extreme events have occurred every 15 years on average, due to exceptionally intense high water episodes and landslides (Schafer *et al.* 1990). A well-known example is the Saint-Jean-Vianney landslide of 1971, which also displaced a large amount of sediment. Hence, the local environment is marked by frequent and occasionally intense perturbations.

Because of the low primary production and the high organic matter input, the ecosystem is dominated by a chain of detritivores associated with the seabed. The organic matter is broken down by bacteria, which are themselves food for nematodes, oligochaetes, and harpacticoid copepods. Higher up the food chain, the main species are amphipods, polychaetes, gastropods, and pelecypods.

The benthic fauna of the north arm and Ha! Ha! Bay is composed chiefly of colonizing species (Pearson and Rosenberg 1978), such as the tubicolous polychaetes *Capitella capita* and *Polydora quadrilobata* (Bossé *et al.*, in press). Other inhabitants include species generally associated with a secondary colonization phase, for example, *Nephtys neotena*, *Thyasira gouldii*, *Prionospio steenstrupi,* and *Lumbrineris minuta.*

The Saguenay floods had a devastating impact on the benthic fauna, which are major components of the ecosystem. For example, sediment sampling in August 1996 revealed that there were no visible organism in the upper layers. Local populations of nematodes, oligochaetes, and polychaetes may have experienced mass mortalities. In addition, an appreciable proportion of mobile species such as cumaceans, harpacticoid copepods, and amphipods are mobile and may have settled elsewhere. As mentioned earlier, at the scale of this benthic community's life cycle, the recent flooding was a more extreme episode than usual, and the repercussions on benthic fauna may be similar to the impacts of the 15-year flood events. Nevertheless, this type of community has the ability to recover quickly. The bacterial microfauna and the meiofauna (size range of 0.1 to 1 mm) of nematodes are constantly replenished at the surface and pioneering polychaetes have very high larval production rates. In general, the event was catastrophic for the benthic fauna, but it will result in only a temporary population reduction.

3.6. FISHERY RESOURCES

The species diversity of fisheries resources of the Saguenay Fjord is relatively well known. The main fish species of interest in the fjord, especially for winter sport fishing, include rainbow smelt (*Osmerus mordax*), cod (*Gadus morhua*), redfish (*Sebastes* sp.), and Greenland halibut (*Reinhardtius hippoglossoides*). The Saguenay Fjord is also occasionally frequented by a number of migratory fish species, such as Atlantic salmon (*Salmo salar*) and American eel (*Anguilla rostrata*), as well as some freshwater fish, including northern pike (*Esox lucius*) and yellow walleye (*Stizostedion vitreum*). Furthermore, the deep waters of the Saguenay Fjord are home to a few fish and invertebrate species that are typical of the arctic seas and are believed to be relict species that were stranded during the last deglaciation (Bossé 1993; Bossé *et al.* 1994). Finally, snow crab (*Chionoecetes opilio*) and northern shrimp (*Pandalus borealis*) are also present in the marine waters of the Saguenay Fjord. Since these species are mobile and can avoid being buried in sediment, it is unlikely that they suffered mortalities in the aftermath of the Saguenay floods.

Little is known about the distribution, abundance and biology of fisheries resources in the Saguenay Fjord, however, since most information, except for the crab, comes from the winter sport fishery, which takes place at numerous spots within the zone affected by floods (Talbot 1992). The majority of marine species targeted by the winter fishery are caught at all the different sites. This suggests that their distribution encompasses the entire inner basin of the fjord and Ha! Ha! Bay. However, snow crab are probably not present in the upstream part of the Saguenay Fjord. Most landings of cod and redfish are made in the water column, whereas Greenland halibut are usually caught near the bottom. Catch data of this type shed light on the species' vertical distribution in fjord waters.

In the short term, the anticipated decline in benthos abundance in zones of high sediment accumulation should reduce food availability for species that feed on benthic organisms. As a result, opportunistic feeders like cod might turn to other food sources while species that are directly dependent on benthos should move to bottom areas where feeding conditions are more favourable. This situation would likely last until the new surface sediments are recolonized by benthos.

3.7. ICE FISHING

Ice fishing is an important tourist activity for the Saguenay region. The main fishing sites are located in Ha! Ha! Bay, at Saint-Fulgence, Sainte-Rose-du-Nord, Éternité Bay and L'Anse-Saint-Jean. Over the 11-week period, this activity generates attendance of more than 200,000 person-days at all the sites combined (Argus Groupe-Conseil, cited in Mousseau and Armellin 1995).

According to preliminary data, the effect of the July floods on ice fishing in the Saguenay Fjord should be mainly physical or mechanical. Assuming that the disaster did not cause a mass flushing of marine fish populations from the fjord, the assorted debris and large quantities of sediment dumped on certain sites could limit fishing activities. In a number of locations, the shoreline has been altered considerably and it may not be possible to place the fishing shacks where they were before. Furthermore, access to the entire water column might be restricted in numerous spots because of the debris covering the bottom of the fjord. As well, changes in the distribution of fish populations can be expected in view of the possible changes in food availability.

Based on the latest communications with fishermen's associations, the main ice fishing sites affected are situated upstream in the fjord. Grande-Baie has been particularly hard hit. Sediments

cover a large portion of the area where the fishing shacks were previously located, forcing the fishermen to move the sites farther offshore. The distribution of shacks on the Benjamin's Cove site will probably be modified according to the pattern of debris accumulation. In the Saint-Fulgence area, the thin sediment layer that was deposited should not have any effect on fishing, as is true for sites farther downriver. Winter sport fishing activities in the Saguenay Fjord might be disrupted depending on the physical and biological responses of benthic fauna and fish populations to the physical impacts of the disaster.

3.8. FISH HABITATS

The potential effects of the floods on fish habitats in the Saguenay, North Shore and Charlevoix regions are detailed in Tables 2, 3, and 4 according to the type of environment affected, that is, the shoreline, tributaries, and Lake Ha! Ha!.

The main impact on the fjord's shoreline habitat is believed to be a deterioration in the aquatic weedbeds at the mouths of rivers, in bays, and in shallow zones. These habitats are generally not very abundant along the Saguenay, given its predominantly rocky and steep banks (Gagnon 1995). However, the weedbeds are of prime importance for a number of fish species, particularly rainbow smelt and sculpin, which use them as feeding, spawning, and nursery areas (Lesueur 1995; Lemieux 1996).

The aquatic weedbeds are located mainly in the vicinity of Saint-Fulgence and, to a lesser extent, in Ha! Ha! Bay and around the mouths of the Sainte-Marguerite and Saint-Jean rivers (Gagnon 1995). They consist mainly of bulrushes (*Scirpus americanus*) and saltmarsh grass (*Spartina alterniflora*). On the North Shore, aquatic weedbeds are found chiefly at the mouths of major rivers and around Manicouagan Peninsula, which also has some eelgrass beds (Lemieux and Lalumière 1995).

In the Saguenay, the weedbeds in Ha! Ha! Bay experienced the strongest disturbances. As a result of the floods, some weedbeds were buried by assorted debris and especially by sediments transported by swollen rivers. A reduction in the extent of these plant communities and in their biological productivity can therefore be expected. Sediment deposition varies in magnitude depending on the area, the current dynamics, and the distance of the weedbeds from river mouths. On the North Shore, there would be little or no impact, since the aquatic plant communities are situated fairly far from the mouths of rivers devastated by the flood waters.

In Ha! Ha! Bay, effects should be felt only over the short and medium term, since plants will gradually recolonize the environment in the coming years. However, fish species that have lost part of their spawning and forage areas may be affected over the short term.

In the river, fish habitats were heavily impacted in tributaries of the Saguenay, especially the Chicoutimi, Sables, Mars, Ha! Ha!, and Saint-Jean rivers (Figure 3). Indeed, an analysis of aerial photos showed that the lower reaches of these rivers were completely transformed. The magnitude of the freshet was so great that whole sections of riverbank were washed away and the channel of the rivers was widened considerably; in some spots, a new channel was created. In general, the flow pattern and particle-size composition were profoundly altered. The length of the bank sections affected varies among rivers, but stretches of up to about 10 kilometres were affected on the Mars and Ha! Ha! rivers.

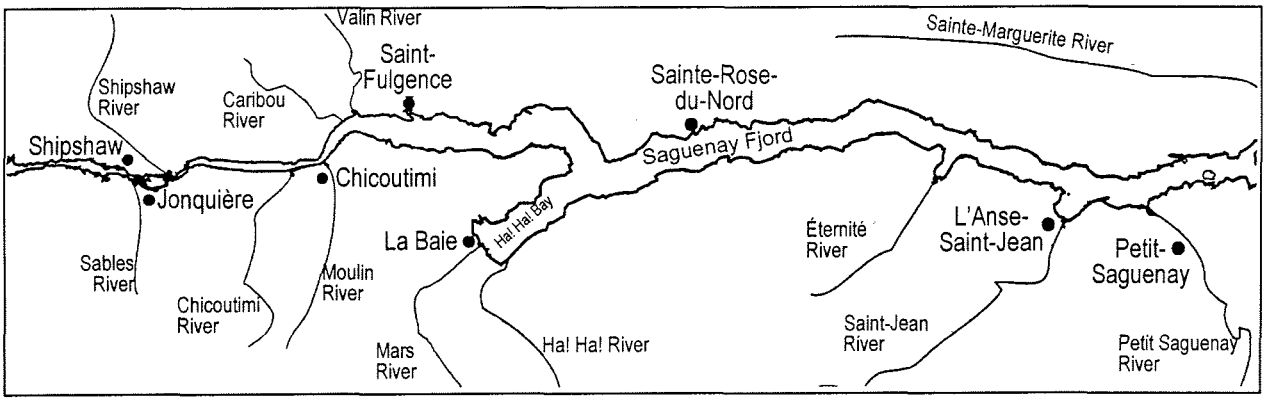

Figure 3. Location of rivers affected by the July 1996 floods in the Saguenay region.

There will probably be substantial repercussions on the many fish species that frequent these waterways, primarily Atlantic salmon and brook trout. High mortality rates may have occurred among early life stages of fish (fry, juveniles) and small-sized species (sculpin, chub), which the flood waters most likely swept away toward the Saguenay. In this regard, it should be noted that the results of electrofishing conducted by the MEF in the Mars, Saint-Jean, and Petit Saguenay rivers shortly after the pulse of water indicated that a drastic decline had occurred in densities of all fish species, particularly young salmonids (Marc Valentine and Omer Gauthier, MEF, pers. comm.). According to MEF biologists, although adult fish are less vulnerable than juveniles, they may also sustained mortalities given the violence of the floods.

Over the longer term, fish populations may be affected by the modification or potential loss of spawning and feeding habitats. The impact should be greater among salmonids, which are especially sensitive to habitat quality. Their spawning areas, consisting mainly of fine materials, gravel, and pebbles, have probably been displaced, partly destroyed, or even washed away entirely. These habitat alterations, coupled with mortalities of adult and early life stage fish, could lead to lower recruitment for several years to come.

On the North Shore and in the Charlevoix region, the damage was less severe than in the Saguenay. Indeed, the main effects observed were landslides or slope erosion in localized spots along waterways characterized by unstable terrain or very fine sediment (sand, silt, clay). Apparently, fish habitats did not undergo any major modifications as they did in the rivers in the Saguenay region; however, slight changes may have occurred (Pierre Dulude, Michel Brault and Alain Gaudreault, MEF, pers. comm.). The main problem is the fine sediment input to the waterways, which means that bottom areas downstream from the affected sites risk becoming clogged, thus impairing spawning grounds. However, these impacts should, however, be fairly localized.

Table 2. Summary of disturbances in the Saguenay region due to the floods.

Sectors	Description of damage	Potential impacts on resources and habitats	Human activities possibly affected	Status	Source and contacts
Saguenay shoreline and river mouths	• Accumulation of debris and sediments around river mouths and shoreline areas • Erosion of banks • Shoreline slumping at L'Anse-Saint-Jean	• Temporary decline in benthic populations • Bulrush and saltmarsh covered with debris and sediments • Potential loss of feeding, spawning, and nursery habitats for fish	• Tourism and recreation • Sport fishing • Ice fishing (especially in Ha! Ha! Bay) • Weir fishing at Saint-Fulgence (eels, smelt) • Navigation	• Ha! Ha! Bay more severely affected than Saint-Fulgence and L'Anse-Saint-Jean sectors	• DFO • McGill University • UQAR • INRS–Océanologie • MEF
Rivers (Saint-Jean, Ha! Ha!, Mars, Chicoutimi, Sables)	• Major overflow of banks • Major modification of riverbeds extending over many kilometres • Severe riverbank erosion, including the complete loss of sections • Displacement of the channel of the Ha! Ha! and Mars rivers • Destruction of the fish ladder on the Mars River	• Modification and potential loss of habitat for benthic fauna and migratory and freshwater fish (known spawning grounds: brook trout in Saint-Jean River; salmon in Mars River) • Decrease in recruitment due to expected mortalities of early life stages of fish (eggs, larvae, fry, juveniles) • Expected mortality of adult fish of several species • Potential impact on migratory routes (salmonids, eels)	• Tourism and recreation • Sport fishing • Outfitter operations • Infrastructures and homes	• Marked decline in fish densities of fish in some rivers following the flood event	• MEF
Lake Ha! Ha!	• Ha! Ha! Lake partly emptied owing to destruction of the dike	• Shoreline of the lake dried up • Temporary loss of habitat for benthic fauna and fish populations • Potential decline in benthic and fish populations (brook trout, Arctic char)	• Tourism and recreation • Outfitters	• Contract to rebuild dike awarded	• MEF

Table 3. Summary of disturbances on the North Shore due to the floods.

Sectors	Description of damage	Potential impacts on resources and habitats	Human activities possibly affected	Status	Source and contacts
Banks of the lower St Lawrence estuary	• Accumulation of debris and sediments at the mouth of the Saguenay Fjord and along the banks of the St Lawrence (Escoumins, Pointe-à-Boisvert, Portneuf bank, baie Verte, and Sault-au-Mouton) • Increased sedimentation possible in salt-marsh	• Potential effect of the additional influx of freshwater on ecosystem productivity	• Minor damage at the Portneuf marina	• Portneuf bank has been cleaned and wood burned, but plastic debris has not been collected • Shoreline cleanup begun at Forestville; completed at Sault-au-Mouton	• DFO • Municipalities • Marsh interpretation centre (Saint-Paul-du-Nord) • Portneuf tourism committee • Baie Verte Committee (Forestville) • MEF
	• Toxicity due to an exceptional bloom of toxic algae observed in August along the Gaspésie. Temporary impact	• Mortalities of marine fish and birds observed in August; low mortalities compared with population size		• Situation back to normal after August	• DFO

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Table 3. (continued).

Sectors	Description of damage	Potential impacts on resources and habitats	Human activities possibly affected	Status	Source and contacts
Rivers (Escoumins, Éperlan, Portneuf, Sault-aux-Cochons, Trinité, Godbout)	• Overflow equivalent to very high spring freshets; slightly higher on the Escoumins and Sault-aux-Cochons rivers • Slight modification of the channel of Sault-aux-Cochons River • Many landslides and slumping of steep riverbanks • Beaver dams and water level regulation works destroyed • Minor damage to fish ladders on the Escoumins and Godbout rivers and major damage on Trinité River.	• Slight modification and/or potential loss of habitat for migratory and freshwater fish • Potential clogging of habitats (spawning grounds) by fine sediments downstream from landslide areas	• Tourism • Infrastructure damage (sewer, water supply, stream crossings)	• The impacts in the region were mainly limited ones. It is difficult to determine at present whether there have been any real effects on resources. Fish ladders have been repaired and are now operational	• DFO • Municipalities • Marsh interpretation centre (Saint-Paul-du-Nord) • Portneuf tourism committee • MEF

Table 4. Summary of the disturbances in the Charlevoix region due to the floods.

Sectors	Description of damage	Potential impacts on resources and habitats	Human activities possibly affected	Status	Source and contacts
Rivers (Gouffre, Malbaie)	• Malbaie River overflowed its banks • Bed of the Malbaie River likely altered in places • Slumping of steep banks and/or landslide on the Malbaie River • Slight damage to the two Donohue dams on the Malbaie River • Breach of beaver dams and damage to lake water control works	• Slight modification and/or potential loss of habitat for migratory and freshwater fish • Potential sediment clogging of habitats (spawning grounds) downstream from landslide areas	• Tourism	• Damage was limited mainly in the Malbaie River; the Gouffre River received a pulse of water similar to a very large freshet	• MEF

Finally, it should be mentioned that Lake Ha! Ha! was virtually drained of its water after a dike was destroyed, and this undoubtedly had a severe impact on fish populations. First, it is very likely that the lake populations, including brook trout, Arctic char, and white suckers, declined sharply because of a mass downriver flushing toward the Saguenay. In addition, the drop in water level exposed a major part of the lake bed and probably reduced food availability.

4. CURRENT AND FUTURE ACTIONS

To better evaluate the nature and extent of this event's impacts, additional information on the bathymetry and the present state of the environment and use patterns. The following paragraphs provide a brief description of short- and long-term measures that should be implemented.

4.1. BATHYMETRY

A Notice to Mariners has already been issued to inform mariners of possible sediment deposits resulting from the floods. In addition, the Canadian Hydrographic Service conducted revisory bathymetric surveys to ascertain the need for more detailed surveys and for new charts covering the most likely affected navigation zones, especially the port of Chicoutimi and Ha! Ha! Bay.

More specifically, the following actions are being taken :

- Reconnaissance surveys of the affected sectors, that is, the Charlevoix, Saguenay (done in September 1996) and Upper North Shore regions, to compare the present situation with the existing nautical charts and Sailing Directions;
- A preliminary bathymetric survey was conducted in the most likely affected navigation zones, and analyses are in progress to evaluate discrepancies between the findings and existing products (maps and Sailing Directions);
- The determination of the type and scope of the detailed bathymetric survey required, the identification of the nautical charts and Sailing Directions affected, and the determination of the type of update needed (Notice to Mariners, chart amendment patch, new editions, or new charts).

4.2. ICE FISHING

Since the winter of 1995, DFO has been carrying out an ice fishing sampling program in partnership with the MEF, Heritage Canada, Alcan Smelters and Chemicals Limited and fishermen associations and committees. The program has two aspects, both encompassing eight sites: L'Anse-Saint-Jean, Éternité Bay, Saint-Félix-d'Otis, aux Battures, Grande-Baie, Benjamin's Cove, Saint-Fulgence, and Sainte-Rose-du-Nord.

The first part of the program, in which fishermen participate on a voluntary basis, is aimed at determining the biological characteristics of the fish caught. Under the second part, an observer posted at each site is in charge of estimating the total fishing effort of all fishermen. The data that are collected will be used to estimate catches per unit of effort for each species.

DFO will continue the program, as planned, during the 1996-1997 ice fishing season. The sampling will permit pre- and post-flood comparisons of fishing results, and conclusions can be drawn from those results. However, numerous factors can influence interannual fluctuations in

fish populations. This sampling program will have to be operated for a number of years to permit evaluation of long-term effects.

4.3. STATE OF THE MARINE ENVIRONMENT

In view of the exceptional nature of the July floods, it is difficult to determine the impacts on the environment and living organisms. Additional samplings should answer the following general questions:

- What effect has the sediment influx had on benthic fauna in the marine environment, particularly Ha! Ha! Bay?
- Have the chemicals that were carried away by the flood waters contaminated the environment (water and sediments) and organisms?
- In what way and how fast will the biological communities in disturbed habitats respond to the changes? Which organisms will recolonize the environment?

We already have some baseline data collected in 1990-1991 in the inner basin of the fjord by a Department of Fisheries and Oceans team (Bossé *et al.*, in press). These data on benthic fauna constitute the only adequate biological sample indicative of pre-flood conditions. This survey could be repeated several times during the same period using the same methods at the same sites. This approach would provide evidence on the recolonization of disturbed environments. It would also provide the opportunity to develop indicators of biological community succession and to assess post-impact conditions.

Hence, answers to the above questions will be sought through a combination of field measurements and temporal monitoring of the different characteristics of the environment and of biological communities. Besides the scientific cruise of McGill University in August 1996, many initiatives are currently in process, in preparation, or under discussion:

- DFO initiated the collection sampling in the Saguenay Fjord in September 1996 to verify the level of chemical contaminants in fish muscle.
- Between 20 and 25 September 1996, UQAR and INRS–Océanologie, sampled 14 stations in Ha! Ha! Bay and 5 stations elsewhere in the fjord. Data collected on the water column, sediments, and benthic communities are being analysed. A scientific report will be produced by February 1997 (Émilien Pelletier, INRS–Océanologie, pers. comm.). UQAR and INRS will continue their work in Ha! Ha! Bay to study the recolonization by the benthic fauna and the evolution of the contamination of the new sediment layer.
- Laval University plans to carry out a geophysical research cruise in the Saguenay Fjord in the spring of 1997.
- DFO will continue its ice fishing monitoring program in the winter of 1997. In addition, fish will be sampled at the fishing sites to measure contaminant concentrations.

5. RECONSTRUCTION PROJECTS THAT MAY REQUIRE AN ENVIRONMENTAL ASSESSMENT

As might be expected, the regions where reconstruction work is most needed are those where the flood levels were highest and where anthropogenic activities had already altered the environment

to the greatest extent. For example, the Alma, Chicoutimi, Jonquière, and La Baie regions are major industrial centres with well-developed port facilities. Water level regulation works and hydroelectric plants have substantially modified natural hydrological conditions there (Sables, Shipshaw, Chicoutimi, Moulin, Mars, Ha! Ha!, Saint-Jean, and Petit Saguenay rivers). In addition, urban and industrial development has spilled over onto floodplain areas where encroachment and backfilling have affected an estimated 233 ha of shoreline. The summer floods therefore call for corrective measures that may require environmental assessment.

Following the floods, the legal context of environmental assessment processes was temporarily modified for the administrative regions of Saguenay–Lac-Saint-Jean, the North Shore, Mauricie–Bois-Francs, and Quebec. Appendix 1 summarizes this context.

Table 5 summarizes the main reconstruction projects that are under way or planned for the Saguenay, North Shore, and Charlevoix regions. It is a preliminary list of known projects and provides only the general framework for environmental assessment.

6. CONCLUSION

This report provides an initial assessment of the potential impacts of the July 1996 floods on the marine environment and freshwater habitats in the Saguenay, North Shore, and Charlevoix regions.

Overall, it appears that the most heavily impacted sectors are situated in Ha! Ha! Bay and on various waterways in the Saguenay area. On the North Shore and in the Charlevoix region, damage to the marine environment and freshwater habitats was much less severe and less widespread than in the Saguenay. The main impacts observed along Saguenay tributaries consist in severe erosion of the riverbanks and bed, along with a mass flushing of fish species with the freshet. The alterations observed in the marine environment are attributable to the influx of sediments and assorted debris which were deposited on bottom areas. These deposits have likely had devastating effects on benthic fauna and aquatic weedbeds, resulting in a loss of spawning and feeding habitats for many species.

As this assessment is based on preliminary and incomplete information, scientists will continue the evaluation work based on new data from various scientific samplings. Results of these observations will allow, if required, the recommendation of measures required for further assessment of the state of the marine environment, the fisheries resources, and the use of the Saguenay marine environment.

Several reconstruction projects could eventually be subjected to environmental assessment. Depending on the nature of the projects and the type of assessment, DFO will play its role with regards to marine resources and fish habitat management.

Table 5. Partial list of reconstruction projects that could eventually trigger provisions of the *Canadian Environmental Assessment Act* in the Saguenay, North Shore, and Charlevoix regions.

Site	Description of damage and work under way
	Saguenay
Lake Ha! Ha!	Destruction of the Lake Ha! Ha! dike, lake emptied. Cofferdam for the reconstruction work already installed. Bridge downstream from dam damaged. A temporary bridge is already in place.
Jonquière (Sables River)	Erosion of slope near the Boulevard Harvey bridge. Landslides in certain spots. Water intakes damaged (municipalities, Alcan, Abitibi-Price, Cascades).
Chicoutimi (Chicoutimi River)	Rebuild the base of the municipal bridge. Bridge ramp near Price Street to be rebuilt. Filtration plant damaged. Gas pipeline to be moved under the bridges and relocated under the riverbed. Dike at the Chute à Garneau dam to be repaired, diversion channel already under construction. Erosion of riverbanks and undermining problems near Laterrière bridge.
Chicoutimi, (ZEC Mars-Moulin)	5 km of highway washed away, including bridges and culverts.
Ville La Baie (Ha! Ha! River)	Many infrastructures and dwellings destroyed. Stabilization of eroding banks to be carried out. Bridge on Highway 170 and municipal bridge to be demolished and replaced by a single bridge over the river.
Town of La Baie (Mars River)	Fish ladders destroyed. Alcan railway bridge to be rebuilt. Railway bridge on Saint-Pierre Road to be rebuilt. Municipal bridge to be demolished and rebuilt according to the new riverbed, near the old salmon fish ladder. Riverbank erosion near the provincial bridge, temporary protection consisting of concrete blocks already in place.
L'Anse-Saint-Jean (municipality)	Municipal bridge destroyed, temporarily replaced with 4 culverts. Reconstruction of a permanent bridge planned before the winter. Stabilization of eroding banks to be done, and dredging in areas with sediment accumulation .
L'Anse-Saint-Jean (ZEC Mars-Moulin, Brébeuf)	Portion of highway affected, including stream crossings.
	North Shore
Portneuf	4 km of forest roads washed away. Marina affected. Extent of damage to be verified.
Forestville	Riverbank erosion. Many forest roads and bridges destroyed.
Sault-au-Mouton	Water supply system affected.
Baie-Trinité	Walls of fish ladder damaged. Extent of damage to be verified.
Godbout	Fish ladder affected. Extent of damage to be verified.
	Charlevoix
ZEC des Martres	Severe damage to roads.
ZEC de la rivière Blanche	Incubator damaged.
ZEC du lac Buteau/ Bas-Saguenay	Fish ladder on Lake Buteau damaged.
Malbaie River, Parc des Hautes-Gorges	Dam damaged, tourist operations interrupted (bateau mouche, canoeing).

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Appendix 1. Context of environmental assessment following the 1996 floods.

On July 22, 1996, the Quebec government ordered (order 934-96) the suspension of provincial environmental assessment procedures for work required to repair or prevent damage arising from the July floods in the administrative regions of the Saguenay–Lac-Saint-Jean, North Shore, Mauricie–Bois-Francs, and Quebec City. The decree order did not specify how long these exemption measures would be in effect.

The Environmental Assessment Branch of the MEF has taken steps to reinstate the normal evaluation process beginning in the fall of 1996. At this time, the MEF should resume consultations with federal authorities concerning matters under their jurisdiction (marine resource management, fish habitat, navigable waters protection, etc.).

Furthermore, under the *Canadian Environmental Assessment Act* (CEAA), some initiatives of federal agencies are required to undergo an environmental assessment. The CEAA also contains a provision whereby some projects can be exempted from the evaluation process in emergency situations (section 7(c)). To date, this measure has been invoked in the context of the *Navigable Waters Protection Act* (NWPA) to allow urgent specific reconstruction projects to go ahead. However, the *Fisheries Act* (FA) and the NWPA (for projects other than the ones mentioned above) might eventually trigger CEAA. Financial contributions from federal agencies for various reconstruction and recovery projects might also necessitate the Acts application. The mandate of the federal reconstruction and recovery committee will include assurance of interdepartmental co-ordination of actions subject to the CEAA.