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Please note

This Digest summarizes an extensive report[1] on the flood-proofing of buildings by a firm of consultants for the Department of Fisheries and Environment Canada. The report assesses several methods of flood-proofing new and existing structures in Canada. Examples of design modifications, materials used, and costs for various types of structure under different flood conditions are listed to illustrate the factors that should he considered.

Flood-proofing, or the design of buildings that can resist floods, is a means of reducing potential damage to structures built in flood plain areas. Existing buildings located in fringe flood zones or in areas where protection works such as dykes may not be adequate can be protected by design provisions. If flood control works are not economically feasible, the flood-proofing of new buildings may be an alternative way of flood protection, part of a comprehensive flood plain management program.

Feasibility of Flood-Proofing

An assessment of flood-proofing requires comprehensive study. Owners, builders, architects, engineers, municipal officials and planners - all must appreciate the need for detailed study of many interrelated factors in assessing the feasibility of flood-proofing buildings.

Factors Related to Flood Characteristics

1. Height of maximum flood level. The lower the depth of flooding the easier it is to floodproof.
2. Velocity of water flow during flood peaks. The lower the flow velocity the easier it is to design a building to resist flood waters.
3. Duration and frequency of floods. The longer the area is flooded, the more difficult and expensive is the flood-proofing.
4. Other factors such as movement of ice during winter floods can also be important.

Structural Factors

When flood waters surround a building they impose uplift and lateral loads on the structure and substructure. The pressures exerted by these loads must be determined in order to design adequate flood-proofing. Most commercial and industrial buildings have sufficient anchorage and connections and are massive enough to resist lateral forces produced by flood water. In

contrast, residential buildings often require special design modifications because they do not have the necessary anchorage and are not massive enough to resist lateral forces.

Uplift and lateral forces against a foundation slab and walls, caused by infiltration of flood water through the foundation backfill, are especially significant. In a typical house in Canada a total force of about 400,000 lb (180,000 kg) could be acting upward on the slab of the basement by the time flood water has reached basement window levels; and the lateral force against foundation walls could total 100,000 lb (45,000 kg). It is not surprising that foundation walls of flooded buildings have collapsed under such forces, that floor slabs have been destroyed, or the entire building lifted under buoyant forces.

Economic Factors

The decision to use flood-proofing, alone or in combination with flood protection works such as dykes, requires a cost-benefit analysis. If anticipated benefits exceed estimated costs (amortized on an annual basis), flood-proofing will be economically justified. Costs will vary considerably, depending on local flood characteristics, type and size of structure, financial terms of capital to be invested, and elevation to which the building must be protected. Benefits depend on the estimated flood damage that flood-proofing will prevent.

Basic Flood-Proofing Methods

Buildings on Fill

New subdivisions or single buildings are often constructed on fill raised above the design flood level. This method is used most extensively for flood-proofing new buildings in Canada. It does not require design modifications, and if the design flood water level is exceeded, the depth of water over the fill will be shallow and of short duration. It is not, however, a practical alternative for protecting existing buildings.

Buildings on Piers, Piles, Columns or Bearing Walls

Elevating structures above design flood level on some kind of support provides reliable protection against flood damage. This method uses land efficiently, does not raise the flood level, and has minimal adverse effects on flood flows.

This alternative requires careful design to prevent damage of supports from floating debris and to allow sufficient space for it to pass underneath. It cannot be used for large existing buildings and may be difficult to apply even to small, light structures.

Making Lower Levels of Building Watertight (Closure and Seal Method)

Flood-proofing the lower levels of buildings by sealing them against water penetration requires that they be made strong enough to withstand cracking from the lateral and uplift pressure of the water. Accordingly, careful design of drainage systems, floor slabs, basement walls, lower windows and all entrances is essential. This method can be used for existing structures if they are of adequate strength and built on soils of low permeability.

The method requires an adequate flood warning system and pre-planned evacuation measures, for there is greater risk of catastrophic damage if design flood level is exceeded. It is not suitable for floods of long duration or where high flood depths are possible.

Surrounding Buildings with Flood-Proof Walls or Berms

This method involves generally the same considerations as those required in the design of small dams. It has several disadvantages such as increasing the possibility of catastrophic failure and is not practicable for individual buildings in dense urban areas.

Wet Flood-Proofing

The preceding four methods are sometimes termed "dry" flood-proofing to distinguish them from so-called "wet" methods in which it is accepted that the interior of the building will be flooded. Flood damage is kept to a minimum by using special water-resistant construction

materials in the lower levels of the building. Wet flood-proofing is frequently the only method of controlling or reducing flood damage to existing buildings in areas subject to flooding. It is seldom advocated for new buildings because of the cost of drying out, the delay in return to use, and the clean-up required after a flood.

Flood-Proofing Services

All services of flood-proofed buildings - electrical, heating, road, sewer - must also be protected from flood damage. Sewers and water pipes can be protected by special valves; telephone equipment and electrical transformers must be located above design flood levels. Auxiliary generators may have to be installed, and hydro lines, access roads and bridges to buildings must be protected. Buried hydro lines and gas mains must be located and designed to resist damage from possible flood erosion or uplift forces.

Flood-Proofing Basements

Flood-proofing of basements can be a special problem for residences situated in a fringe flood zone where only the basements may be flooded. Here there are two basic flood-proofing methods:

1. an "undrained" system designed to be watertight, with sufficient strength and mass to withstand uplift and lateral forces;
2. a "drained" system using more conventional wall and slab design with a sump pump operation to keep uplift and lateral forces in the soil to a minimum.

The principal consideration in choosing between the two methods is the permeability of the surrounding soil and backfill material around the basement walls. The first method requires additional basement wall protection, high quality construction and special drainage control methods. The second method requires a sump pump with the capacity to pump out infiltration inflow at a rate sufficient to limit the build-up of excessive hydrostatic pressure. It should only be considered if reliable electrical power can be provided during flood conditions. Both methods require professional advice from experienced soils engineers.

Case Studies

Twelve case studies are presented in the report[1] not only to illustrate the use of flood- proofing in Canadian structures but also to give some indication of possible costs. Design modifications were made to several structures using various flood-proofing methods.

The majority of the case studies were assessed for flood depths of from 3 to 5 ft (1 to 1.5 m), approximately the average flood depth in the flood plains across Canada. They included industrial buildings, apartments, commercial plazas and a single-family residence (Table I). Drawings and itemized sheets of structural materials were compiled for each structure and are published as a separate volume.

Table I. Flood-Proofing Case Studies, New Structures[1]

Case Study	Type of Building	Design Flood Level		Flood-Proofing Method
		ft	m	
1,2	Industrial	3	(0.9)	Closure and Seal

3,4	Industrial	5	(1.5)	Closure and Seal
5,6	Industrial	5	(1.5)	Elevation on Fill
7	Apartment	6	(1.8)	Elevation on fill
8	Apartment	5	(1.5)	Flood wall
9	Apartment	5	(1.5)	Elevation with closure and seal
10	Single-family	3	(0.9)	Elevation on bearing walls
11,12	Commercial plazas	3	(0.9)	Elevation on terraced fill

Case Study Conclusions

1. New or existing buildings can be "dry" flood-proofed for the majority of flooding conditions that occur in Canadian fringe flood areas provided detailed studies of structures, soils and hydraulics are carried out.
2. Estimates of "dry" flood-proofing costs vary from as little as 2 per cent of the capital cost of the building to more than 50 per cent, reflecting the effect of type of structure and site conditions (Table II).

Table II. Overview of Flood-proofing Costs For Case Studies[1]

Type of Structure	Area		Percentage of Total Value of Building	
	ft²	m²	New	Existing
Single Family	<1600	(150)	2-12	11-50
Commercial/Retail	22,500	(2080)	6-16	Variable
Multi-storey	61,600	(5750)	3-7	3->7
Industrial	90,500	(8400)	2-4	2-4

3. Flood-proofing is less expensive for new structures than for existing buildings because the requirements can be introduced in the planning and design stages.

4. Although the total cost of flood-proofing usually increases with the size of structure, the cost per unit area is usually less for large buildings.
5. Elevating new houses and small commercial structures above expected flood levels is generally the cheapest flood-proofing alternative.

General Conclusion

Although flood-proofing has rarely been considered in Canada as an alternative to zoning or flood protection works, it may be viable under some circumstances. For example, the capital outlay for flood-proofing industrial buildings in a flood plain is often much less than that for expropriation, relocation, or major flood control works.

The potential advantages of flood-proofing are greatest in metropolitan areas where low-hazard flood lands have already been developed or where great pressure is being exerted to use underdeveloped land in the fringe of defined flood zones. Selective flood-proofing can be carried out in these areas with safety and often with greater economy than other forms of flood plain management.

Reference

1. Canada, - Department of Fisheries and Environment. Flood Proofing: A Component of Flood Damage Reduction. Prepared by J. F. MacLaren Ltd., March 1978. Vol. I; Appendix A, A Portfolio of Canadian Case Studies is published separately as Vol. II. (Available from Environment Canada, Distribution Centre, 131 Greber Blvd., Pointe Gatineau, Quebec J8T 3R1.)

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