



FLOOD RISK EVALUATION AND FLOOD CONTROL SOLUTIONS PHASE 2 - FINAL REPORT

SEPTEMBER 2009

nhc
northwest hydraulic consultants

McElhanney Consulting Services Ltd.

CITY OF PRINCE GEORGE FLOOD RISK EVALUATION AND FLOOD CONTROL SOLUTIONS PHASE 2 - FINAL REPORT

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This project was conducted under the guidance of Dave Dyer, P.Eng., Chief Engineer - City of Prince George, who throughout the project provided information, direction and advice. Bob Radloff, P.Eng., Director Development Services and Dan Milburn, MCIP, Manager of Long Range Planning, both of City of Prince George, reviewed reports and provided valuable comments.

Fraser Basin Council (FBC) organized public consultations on June 16 and 17, 2009 and provided a summary of the input received. This work was lead by Steve Litke, Senior Manager; Joan Chess, Sustainability Facilitator, Northern Region; and, Jillian Merrick, Associate Regional Manager, Upper Fraser Region.

The development of flood control options and corresponding cost estimates were carried out chiefly by McElhanney Consulting Services Ltd. (MCSL), under the direction of Bill Cheung, P.Eng. Phase 1 geomorphologic and sedimentology investigations were completed by Mike Miles, P.Geo. of M. Miles Associates Ltd. (MMA) and environmental investigations were undertaken by Environmental Dynamics Inc. (EDI), led by Rob Van Schubert, R.P.Bio. The project team was managed by Bruce Walsh, P.Eng. of Northwest Hydraulic Consultants Ltd. (NHC). Ice analyses were performed by David Andres, P.Eng. and NHC also undertook hydrologic and hydraulic investigations, with modelling and graphics output completed by Guilherme de Lima, Ph.D. Project engineering was by Monica Mannerström, P.Eng. who also compiled the reports. Kevin Brown Communications Ltd. assisted with the launch of the Phase 1 report.

The present Phase 2 report was prepared by NHC and MCSL and built on the information received during the public consultations as summarized by FBC.

EXECUTIVE SUMMARY

The City of Prince George experienced severe ice-related flooding in the winter of 2007-2008 that caused extensive damage to areas along the Nechako River. A few months earlier, during the spring of 2007, the Fraser River overflowed its banks, also causing damage. To reduce the potential for future damage, the City retained a team of consultants to assess flood risks and develop flood control solutions.

The project was carried out in two phases, with the first phase encompassing assessment of flood risks and development of flood control options (NHC et al, 2009). Seven flood risk areas were identified along the Nechako River and another seven along the Fraser. In the second phase, described in this report, community meetings were held to inform the public about the Phase 1 findings and to obtain input on the preliminary proposed flood control solutions. The input received was directly applied in the solution selection process. Funding for implementing the solutions is limited and the projects had to be prioritized. A matrix approach was adopted which included the following eight criteria: timing of the flood; water depth; flood duration/fluctuation; the number of buildings affected; the type of infrastructure; asset values; the area extent of flooding; and, the cost effectiveness of a solution. Guidelines for further investigations were recommended and steps to implement the solutions developed.

The need for updating the 1997 floodplain maps was confirmed in Phase 1. During the spring of 2009 LiDAR data was collected (under separate contract) and the City is presently processing the data for topographic mapping. The topographic maps, together with the design flood profiles developed in Phase 1 plus a freeboard allowance will form the basis for generating the revised floodplain maps. The maps are necessary before proceeding with the recommended projects. The projects fall into two categories; general investigations and area-specific flood control solutions.

In order of priority, the general investigations and corresponding costs are:

- Select freeboard (minimal cost)
- Revise floodplain maps and City's floodplain regulation bylaw (\$20,000)
- Install pump-test well/level gauges for Area A_N to assess groundwater (\$42,500)
- Prepare erosion hazard maps (\$25,000)
- Install water-level gauges & develop winter flow monitoring program (\$70,000)
- Develop ice-related flood forecast procedures and public notification policy (\$20,000)
- Develop freshet forecasting procedures (\$25,000)
- Monitor river bed at confluence (\$15,000)
- Monitor future impacts on flood flows (minimal cost)

The total estimated cost of the above projects is \$217,500.

Recommended area-specific projects, also in order of priority, are listed on the next page. Engineering costs shown include additional investigations, hardware, environmental permitting and community consultations. Class D cost estimates were derived in Phase 1 and will need further refinement once floodplain maps are available.

Area-specific projects in order of priority are:

1. **Area A_N – Nechako South Bank at Confluence:**
Setback dike (\$300,000 engineering; \$15.5 M Class D)
2. **Area C_F – Fraser West Bank at Hudson’s Bay Slough West of Queensway:**
Check adequacy of existing protection (\$10,000 engineering)
3. **Area C_N – Nechako North Bank near Confluence:**
Land-use change and local floodproofing (\$50,000 engineering; \$9.3 M Class D)
4. **Area D_N – Nechako North Bank West of John Hart Bridge:**
Raise Preston Road (if supported by further investigations) and/or local floodproofing/land-use change (\$100,000 engineering; \$4 M Class D – assuming road is raised)
5. **Area B_F – Fraser West Bank at South Fort George:**
Local floodproofing/land-use change (\$20,000 engineering; \$2.9 M Class D)
6. **Area B_N – Nechako North Bank East of John Hart Bridge**
Building/infrastructure inventory and wet floodproofing (\$25,000 engineering)
7. **Area E_N – Nechako North Bank at Morning Place:**
Local floodproofing/land-use change (\$15,000 engineering; \$1.4 M Class D)
8. **Area D_F – Fraser West Bank at Lansdowne South End:**
Local floodproofing/land-use change (\$5,000 engineering; \$0.8 M Class D)
9. **Area G_N – Nechako South Bank between John Hart and Foothills Bridges**
Infrastructure inventory (\$5,000 engineering)
10. **Area F_N – Nechako South Bank at Foot Hills Bridge**
Infrastructure inventory (\$5,000 engineering)
11. **Area F_F – Fraser West Bank at Northwood Pulpmill Road**
Inventory and raising of Landooz Road (\$5,000 engineering & predesign; \$5.8 M Class D)
12. **Area G_F – Fraser West Bank across from Shelley**
Water Survey Canada gauge check (\$0)
13. **Area A_F – Fraser West Bank at Yellowhead Highway**
Infrastructure inventory (\$5,000-engineering)
14. **Area E_F – Fraser West Bank at Island upstream of Confluence**
Confirm extent of revised floodplain relative to housing (\$0)

Total engineering costs are \$545,000. Preliminary Class D costs amount to a total of \$39.7 M.

Enlarging the Cottonwood Island side-channel was identified as a beneficial project although it would not reduce Flood Construction Levels in the area. The project would be carried out in 2 parts, with the first part (mainly engineering) at an estimated cost of \$390,000 and the second part (mainly construction) of \$3.5 M.

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1. INTRODUCTION

1.1 PROJECT DESCRIPTION

The City of Prince George experienced severe ice-related flooding in the winter of 2007-2008 that caused extensive damage to areas along the Nechako River. A few months earlier, during the spring of 2007, the Fraser River overflowed its banks, also causing damage. To reduce the potential for future damage, the City retained a team of consultants to assess flood risks and develop flood control solutions.

The project was carried out in two phases, with the first phase assessing flood risks and developing flood control options. In the second phase, described in this report, flood control solutions are selected and the recommended projects prioritized. General guidelines for implementing the solutions are also developed.

The initial start-up meeting for the project was held on April 18, 2008. Progress Report 1 was completed in June, 2008 and presented to Council on July 7, 2008. The Phase 1 draft report was issued in January, 2009. Following review by the City, Emergency Management BC, BC Ministry of Environment and others, the final Phase 1 report was issued in May, 2009. The report was presented to Council on May 25, 2009 and a media release took place on the same day. Public consultations were conducted on June 16 and 17, 2009 as part of the Phase 2 requirements. The FBC final report summarizing the consultations was completed on August 20, 2009, and is appended to this report.

The Phase 1 final report provided a complete technical summary of the project and should be referred to for all background information. For brevity, the information has not been repeated in this report.

1.2 PHASE 2 TERMS OF REFERENCE

The initial Phase 2 terms of reference were as follows:

Public Consultations

Allow for three separate trips to Prince George to participate in public meetings with stakeholders and property owners impacted by the recommendations of the Flood Risk Evaluation. Prepare displays, pamphlets, digital slides for webpage and other education materials for the City's use in presenting the results of the Flood Risk Evaluation and the recommended flood control solutions.

Selected Flood Control Solutions

Summarize the results of the public consultation process and revise recommended solutions to control and provide protection from flooding or to reduce the risk of flooding for floodplain areas on the Fraser and Nechako Rivers. Specific tasks are:

- Flood Control Infrastructure – Based on the flood risk evaluation and public consultation process, identify and evaluate the proposed infrastructure measures complete with cost estimates (Class D) and timelines for property acquisition, regulatory approvals, design and construction.
- Land Use – Identify land use changes that are considered necessary from the risk analysis and the feasibility assessment. Provide timelines and implementation strategies.
- River Solutions – In-river solutions such as gravel extraction and side channel diversion/relief floodways that satisfy the risk analysis and feasibility assessment may require further review with regulatory agencies. Identify the processes necessary to obtain the necessary approvals complete with cost estimates and timelines.
- Revise Floodplain Mapping and Floodplain Regulation Bylaw – Based on forecasts presented in the river hydraulics and ice-related flooding analysis and in conjunction with the BC Ministry of Environment, recommend and prepare revised floodplain mapping for the City of Prince George. Floodplain mapping is to be prepared in accordance with the Fraser Basin Council Floodplain Mapping Guidelines and Specifications (March 2004). The floodplain mapping must be provided in digital format compatible with the City's GIS mapping system. A design brief providing support for the analysis must accompany the mapping. The City's Floodplain Regulation Bylaw No.7855, 2007 will require revision once the floodplain mapping is complete. In addition to adjusting the Flood Construction Level and general exemption sections, the bylaw will need to consider regulations to address properties that are vulnerable to high groundwater.

To generate accurate floodplain mapping, up-to-date detailed topographic base-maps are required. The City retained McElhanney Consulting Services Ltd to collect LiDAR data for the entire City during the spring of 2009. The data is currently being processed and the base-mapping has not yet been completed. In the spring of 2008, LiDAR data was obtained for a limited area at the Nechako/Fraser confluence. This information was used for hydraulic modelling.

Before conceptual designs of the flood control infrastructure can be developed and the Phase 1 cost estimates reviewed, the updated floodplain maps need to be prepared. However, to expedite completion of Phase 2, the City outlined a scope of work that would satisfactorily account for the lack of updated floodplain maps. Incorporating the public input received to date, the Phase 2 work items are as follows:

- Select specific projects that the City can undertake to reduce the potential damage from future floods and summarize the recommendations in a concise reference document.
- Prioritize projects so that the most urgent work is undertaken first. Due to limited financial resources, not all flood mitigation can be introduced at once and the protection measures are to first be implemented at the risk areas with the highest vulnerability and with the highest potential losses.

- Outline the tasks involved with each project including additional data collection, field assessments, design, environmental permitting, construction, future maintenance requirements and project limitations. Provide approximate timelines for each work component and estimate costs. (Considering updated floodplain maps have not yet been completed, costs are approximate only). The information will be used by the City for grant applications and must be suitable for this purpose.
- Highlight which projects require immediate attention and which can be dealt with over the next several years.

2. RISK AREAS AND CONTROL SOLUTIONS

2.1 RISK AREAS

Phase 1 identified a total of 14 risk areas, or developed areas within the floodplain; seven located along the Nechako River and another seven along the Fraser River. The areas along the Nechako are primarily at risk of flooding during the winter as a result of ice-related flooding caused by the Nechako. However, the areas near the confluence are also at risk during the Fraser freshet. The areas along the Fraser River are at risk of flooding during the Fraser freshet only. The following areas were identified:

- Area A_N – South Bank of Nechako River at Confluence
- Area B_N – North Bank of Nechako River east of John Hart Bridge
- Area C_N – North Bank of Nechako River near Confluence
- Area D_N – North Bank of Nechako River west of John Hart Bridge
- Area E_N – North Bank of Nechako River at Morning Place
- Area F_N – South Bank of Nechako River at Foot Hills Bridge
- Area G_N – South Bank of Nechako River between John Hart and Foothills Bridges

- Area A_F – West Bank of Fraser River at Yellowhead Highway
- Area B_F – West Bank of Fraser River at South Fort George
- Area C_F – West Bank of Fraser River at Hudson’s Bay Slough West of Queensway
- Area D_F – West Bank of Fraser River at Lansdowne South End
- Area E_F – West Bank of Fraser River at Island upstream of Confluence
- Area F_F – West Bank of Fraser River at Northwood Pulpmill Road
- Area G_F – West Bank of Fraser River across from Shelley

As specified in the Terms of Reference, flood-prone areas outside the City of Prince George municipal boundaries, such as Foreman Flats and Shelley, were not included.

The risk areas were delineated based on the outdated 1997 floodplain maps. The new flood levels are higher and the inundation areas will increase depending on the floodplain topography. In general, the topography along the 1997 floodplain boundaries is relatively steep and area increases are expected to be small. Only in areas where the topography is flat and the flood levels have increased significantly will the designated floodplain show substantial increases, such as Area D_N – North Bank of Nechako River west of John Hart Bridge and Area E_N – North Bank of Nechako River at Morning Place.

2.2 SUMMARY OF POTENTIAL SOLUTIONS

Section 5.4 of the Phase 1 report provided a preliminary indication of where flood threats are most severe and asset values the highest. Attention was mainly focused on privately owned residential, commercial and industrial development. Tentative projects in an initial descending order of priority were:

1. Area A_N - South Bank of Nechako River at Confluence - Build dike on river side of River Road, providing internal drainage and reducing groundwater seepage.
2. Area C_N - North Bank of Nechako River near Confluence - Introduce land use change south of PG Pulpmill Road. On north side of road land use change or local floodproofing can be considered.
3. Area D_N - North Bank of Nechako River West of John Hart Bridge - Raise Preston Road. Consider land use change or local floodproofing on river side of road.
4. Area B_N - North Bank of Nechako River East of John Hart Bridge - No permanent protection. Provide temporary protection as needed.
5. Area B_F – South Fort George - Introduce land use change as necessary. Optionally local floodproofing can be considered in some locations.
6. Area E_N – Morning Place - Introduce land use change as necessary. Optionally local floodproofing can be considered in some locations.
7. Area D_F – Lansdowne South End - Introduce land use change as necessary. Optionally local floodproofing can be considered in some locations.

The Phase 1 report explained why gravel removals would not alleviate flood levels under current river conditions. However, improvements to the Cottonwood Island side-channel are considered beneficial.

In Phase 1, the following areas were deemed not to immediately require flood control solutions:

- Area F_N – Nechako South Bank at Foothills Bridge.
- Area G_N – Nechako South Bank between John Hart and Foothills Bridges.
- Area A_F – Fraser West bank at Yellowhead Highway
- Area E_F – Fraser West Bank at Island
- Area F_F – Fraser at Northwood Pulpmill Road
- Area G_F – Fraser River across from Shelley

It is recognized that appropriate zoning should be introduced to restrict or discourage further development and the existing infrastructure inventoried in these areas. For example, water wells in Areas F_N and G_N, supply over 80% of the City's water. Well PW601, located in Area G_N, was inundated during the 1996 ice-related flooding and in the winter of 2007-08 the well was shut down to avoid contamination.

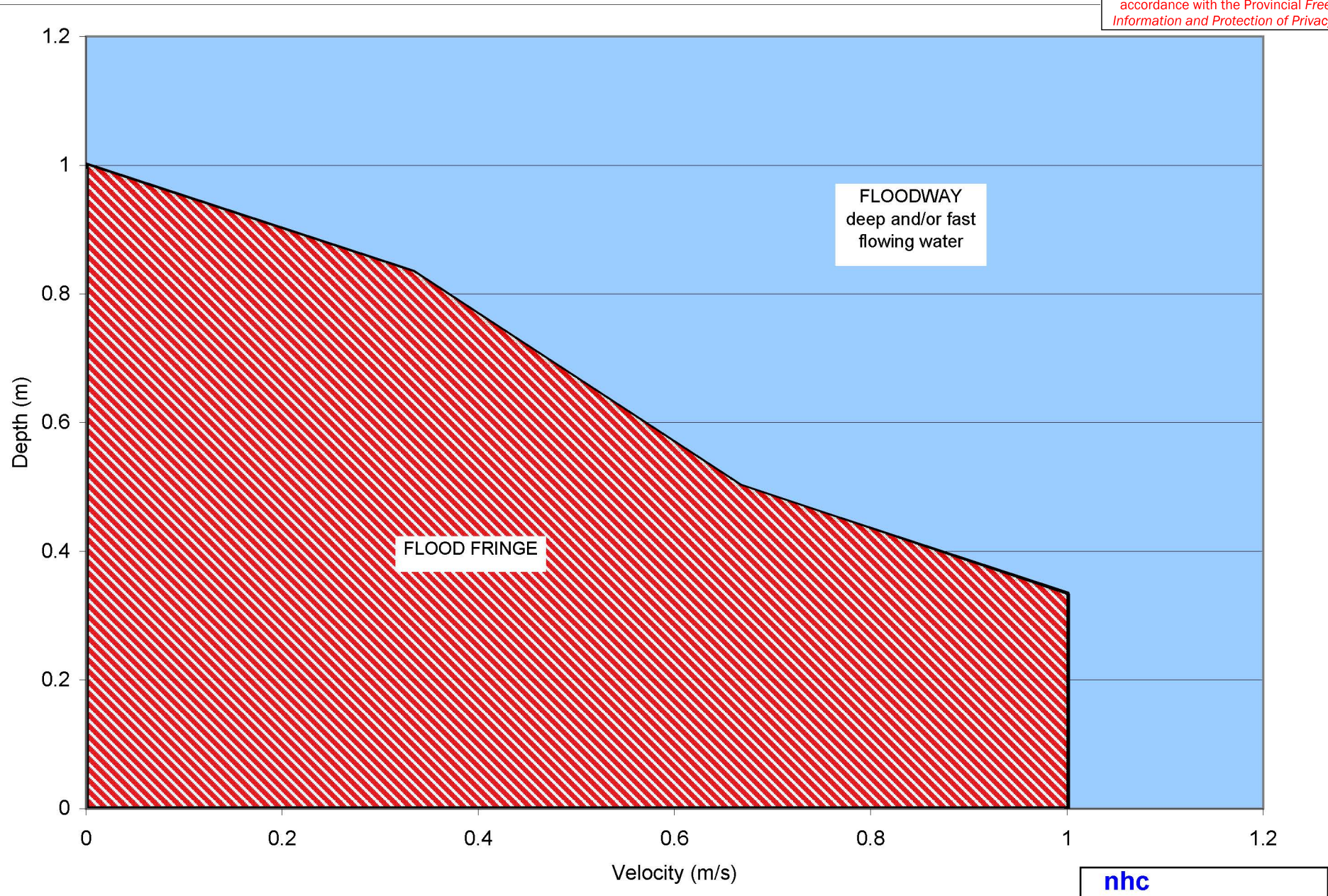
Area C_F – Fraser River at Hudson's Bay Slough west of Queensway has flood protection in place but the adequacy of the present diking and pump facility should be assessed.

2.3 FLOODWAYS AND FLOOD FRINGE ZONES

Traditional floodplain mapping in British Columbia delineates 200-year flood inundation boundaries without distinguishing between floodways, areas of deep or fast flowing water, and flood fringe zones, where flood waters are relatively shallow and slow moving. Typically, this distinction is made in other parts of Canada, the US and Europe to restrict any development within the floodway but to permit appropriately floodproofed buildings within

the fringe zone. Figure 2.1 provides a definition of floodway hydraulic conditions, generally corresponding to velocities exceeding 1 m/s or depths of more than 1 m.

The HEC-RAS hydraulic modelling carried out in Phase 1 was one-dimensional, providing cross-sectional average depths and velocities rather than specific localized values. However, HECRAS has an option for calculating overbank depths/velocities and this tool will be used to approximately define the extent of the floodway zone. In recommending flood control solutions, land-use change will be recommended for all areas within the floodway.



Deep and/or Fast Flowing (DFF) Floodway Classification is based on USBR (1988).

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Flood Fringe and Floodway Classification
August 2009 Figure 2.1

3. PUBLIC CONSULTATIONS

3.1 CONSULTATION PROCESS

The terms of reference specified participating in public meetings with stakeholders and property owners impacted by the recommendations of the Flood Risk Evaluation. The purpose of the meetings was two-fold, to inform the public on the findings of the project and to obtain feed-back information.

The official public meetings were organized and facilitated by Fraser Basin Council (FBC) and were held in the Prince George Civic Centre on June 16 and 17, 2009 with roughly 50 individuals attending both evenings. The first evening was an information session, with the different technical specialists providing brief presentations on river geomorphology, hydrology and hydraulics, ice jams, environmental assessments and flood management options including costs. The presentations were preceded by an open house with handout material available to the public and informative posters on display. The second evening involved community discussions using a “World Café” format. FBC summarized the process and feed-back received in a stand-alone report, included as Appendix A. Flood control solutions were discussed both in general terms and categorized by area.

3.2 SUMMARY OF OUTCOME

A summary of the meeting was provided by FBC with the following concluding remarks:

“The community process served multiple benefits. It provided an opportunity for community members to learn about the findings from the technical analysis both in terms of flood risks and recommended management options. It provided an opportunity for City Council and staff to learn about the interests, knowledge, perspectives and preferences of community members, for consideration alongside the technical facts, figures and analysis.”

Optimal solutions that will provide long-lasting flood protection benefits to the community at large are most likely to be found through listening and learning from a broad diversity of perspectives and insights. In particular, local knowledge can also help build a depth of understanding about site-specific conditions to help tailor creative solutions for particular areas. The community process and the FBC report are intended to share these types of community perspectives with the City of Prince George to support thoughtful deliberations and decisions to manage the flood risks faced by the community now and in the future.”

The technical team greatly appreciates the public’s contribution. Generally, the feed-back fell into three categories: questions, general opinions and specific requests. Technical questions are broadly answered within this report and opinions/requests were incorporated as far as possible in the further development of flood control solutions.

4. GENERAL PROJECTS

Before proceeding with the recommended flood control projects, some further general investigations are required as described in this section. The projects generally correspond to recommendations made in the Phase 1 report. Brief outlines for the investigations are provided, discussing methodologies, constraints, timing and the cost/effort involved.

4.1 FREEBOARD ALLOWANCE

To determine Flood Construction Levels (FCL's) for floodplain maps, a freeboard allowance must be added to the estimated 200-year water levels. The BC Ministry of Environment (MOE) specified freeboard is 0.6 m if the flood level is based on maximum daily flows or 0.3 m if based on maximum instantaneous flows (FBC, 2004). The higher of the two is adopted as the FCL and used for the design of dikes, road crests, floor elevations etc. For both the Nechako and Fraser Rivers, maximum daily flows plus a freeboard of 0.6 m resulted in the higher condition.

Flood management regulations, previously looked after by MOE, have now largely been downloaded to the municipal level. However, diking approvals are still handled by MOE. In view of the increased uncertainty of flood flow estimates caused by climate change and mountain pine beetle infestations, the Phase 1 report recommended reviewing the 0.6 m freeboard allowance and possibly increasing it to 1 m. This would more closely match standards used in many other parts of the world, particularly for densely developed areas.

The cost of diking and floodproofing to a 1 m freeboard standard rather than 0.6 m will be considerably higher. In some instances, for example for raising houses, the higher standard may not be practical. The following alternatives, or a combination of them, can be considered:

1. Use a 1 m freeboard allowance throughout Prince George.
2. Use a 1 m freeboard for dikes and roads but adopt 0.6 m as the standard for floodplain maps and other floodproofing measures.
3. Use a 1 m freeboard for the Fraser River and 0.6 m for the Nechako River, where design levels were determined based on ice-related flooding and are considered more conservative.

MOE is in the process of reviewing dike standards and it is recommended that the City Engineering Department discuss freeboard requirements with MOE. In our opinion, Alternative 2 offers a reasonable approach. Optionally, a freeboard of 0.6 m can be adopted for dikes and road construction as well, but a wider footprint introduced, allowing for dikes/roads to more easily be raised in the future if deemed necessary.

Project Outline:	<ol style="list-style-type: none"> 1. City to contact Neil Peters, MOE Inspector of Dikes, for input on freeboard recommendations. 2. Technical team to determine cost implications of freeboard selection. 3. City to review information and make a recommendation to Council. 4. Council to approve selected freeboard allowance.
Cost:	Minimal
Project timing:	Immediate
Importance:	High

4.2 FLOODPLAIN MAPS AND FLOODPLAIN REGULATION BYLAW

The need to update the 1997 floodplain maps was confirmed during Phase 1. Before any construction/ floodproofing projects are undertaken the new mapping must be completed. The floodplain topography was surveyed in May 2009 under separate contract using LiDAR and is currently being processed. Once the topographic base-mapping is available and a freeboard allowance adopted, the floodplain mapping can be produced. The maps will be prepared in digital format, compatible with the City's GIS mapping system. The mapping will follow Fraser Basin Council Guidelines and Specifications (March 2004) and a supporting design brief will be provided.

Once the Flood Construction Levels (FCL's) are established and floodplain mapping is completed, the City's Floodplain Regulation Bylaw No. 7855 will need to be updated for the floodplain mapping and new FCL's to take effect. The bylaw will need to revise the designated inundation areas (i.e. by way of the floodplain mapping), the regulation of flood elevations (i.e. FCL's), setback limits and general exemptions.

Project Outline:	<ol style="list-style-type: none"> 1. City to complete topographic mapping based on LiDAR data. 2. NHC to review if new mapping changes hydraulic model results. 3. NHC to add adopted freeboard to Phase 1 flood levels. 4. NHC to generate floodplain maps in GIS and prepare design brief. 5. NHC to provide input for City to update Bylaw No. 7855.
Cost:	Approximately \$20,000 following completion of base-maps. (A more accurate cost estimate will be provided once the format of the base-maps is known).
Project timing:	Immediate
Importance:	High

4.3 EROSION HAZARD MAPS

The flood risk evaluation project did not assess bank erosion hazards. As part of the geomorphic evaluation, MMA (2009 b) identified actively eroding sediment source locations but these were mainly located outside the City limits. During a field assessment by boat on June 17, 2009 conducted by the City, DFO, MOE and representatives of the technical team, a number of sites with actively eroding river banks were observed.

Gravel-bed rivers typically undergo gradual change overtime as material is deposited in one area, triggering erosion in a downstream area. The eroded material is in turn deposited some distance downstream causing erosion in another location. This is a natural process that can be observed from the review of Nechako River historical air photographs (MMA, 2008 a). A river may appear stable for many years but can change significantly in response to large flood events such as the 2007 freshet and ice-related floods. In some areas, structures close to the banks may be threatened over time and the City requested that an outline for mapping erosion sites be included in the Phase 2 report.

During the public consultations, one erosion site was mentioned by residents in Area C_N on the north bank of Nechako River, upstream of the fish hatchery off of PG Pulpmill Road. The bank erosion in this location is likely caused by the gradual build-up of two upstream mid-channel bars/islands which direct more flow towards the north bank. The residents questioned if the erosion in part was caused by the emergency response actions taken by the City or Brink Forest Products on the opposite bank. This seems highly unlikely considering the emergency measures did not protrude into the river and therefore would have resulted only in localized hydraulic effects.

No structures along the Nechako River within the City appear to be in imminent danger based on the field assessments in June. However, the need for relocating buildings or installing erosion protection should be assessed and conceptual designs developed as necessary. The sites requiring attention should be prioritized and the costs of mitigation measures estimated. New development in areas at risk should be discouraged and suitable set-back limits introduced.

Project Outline:	<ol style="list-style-type: none"> 1. Map active erosion sites based on photographic data and site visits. 2. Review historic channel shifts. 3. Determine which sites require protection and develop conceptual designs including approximate costs and environmental approval requirements. 4. Prioritize projects.
Cost:	Approximately \$25,000.
Project timing:	Within the next year.
Importance:	High

4.4 FORECASTING TOOLS

Real-time flood-forecasting provides an important flood management tool, particularly for unprotected areas that rely on temporary flood protection. Flood-forecasting is beneficial for both Fraser freshet flooding and Nechako ice-related events. The flood level forecasts can be used for issuing evacuation alerts or orders and aiding with temporary flood protection. In the past three years, NHC has carried out real-time flood level forecasting along the Lower Fraser River for MOE.

4.4.1 FRESHET FORECASTING

During the freshet season, the River Forecast Centre (RFC) of MOE provides five-day flow forecasts at different WSC gauges through out the Fraser River basin. The forecasts are based on snow-pack measurements, modelling using the WARNS runoff model and Environment Canada weather forecasts. Flow forecasts are published on the RFC web-site. By using the predicted flows for WSC Station 08KB001, Fraser River at Shelley and Station 08JC002, Nechako River at Isle Pierre as input to the HECRAS model developed in Phase 1, the water levels in Prince George can be estimated up to five days in advance. The model can be run with little effort and it is recommended that this be done during anticipated high flow years. We recommend installing a series of staff gauges in key areas so that computed and observed water levels can be compared and the model accuracy verified from year to year. The gauges would also provide an indication of any long term changes to the river bed. Based on the HECRAS model, rating curves can be developed for the gauges to provide a quick reference for estimating water levels corresponding to a certain flow.

Project Outline:	<ol style="list-style-type: none"> 1. City to install approximately ten staff gauges in key areas in consultation with NHC. 2. During anticipated high flow years, NHC to run HECRAS model daily, using RFC flows and provide predicted water levels for all key locations. 3. NHC to develop rating curves for the gauges. 4. City staff or reliable locals to read staff gauges during freshet peaks and submit information to NHC for model verification.
Cost:	Approximately \$10,000 for installation of staff gauges and \$15,000 per freshet for reading gauges, modelling and report preparation.
Project timing:	Install gauges this year, run model as needed during high freshets.
Importance:	Medium-high

4.4.2 ICE-RELATED FLOOD FORECASTS

The objective of the ice-related forecasting is to provide an “a priori” assessment of the severity and timing of freeze-up on the Nechako River. It was evident from the work in Phase 1 that the severity of freeze-up can be forecast in advance from considerations of the

Nechako River flows and long range air temperatures. Furthermore, the timing of freeze-up can be determined from observations of ice conditions on the Fraser River. Results from the public consultations suggest that some residents (such as those at Morning Place) might opt for temporary flood protection that would require some lead time to install. In fact, given the time differential between freeze-up at Old Fort George and freeze-up at Morning Place, this option appears to be workable, provided there can be confidence in the forecasting protocols.

Work to improve the forecasting protocols will be required on a number of fronts including:

- Improving the discharge estimates at Isle Pierre.
- Developing a better understanding of the thermal characteristics and ice production rates upstream of Prince George.
- Installing gauges and developing water level monitoring procedures.
- Undertaking an observation program over the next three to five years to improve and fine-tune the forecasting system.
- Developing a public notification system.

A number of groups with specific skill sets and monitoring capabilities will need to be involved in this effort including WSC, the City, NHC and others.

Project Outline:	1. NHC to describe the operational requirements and define forecasting priorities. 2. City to coordinate involvement of salient provincial and federal agencies.
Cost:	Approximately \$20,000 to describe the operational requirements.
Project timing:	Within next two to three years. The existing knowledge base can be used to provide an ad hoc forecasting service that should suffice in the short term.
Importance:	Low in short term, high in long term.

4.5 ICE-RELATED FLOOD FLOW AND WATER LEVEL MONITORING

During the public consultations, it was repeatedly brought up that Rio Tinto Alcan (RTA) should be held responsible for their flow releases at Skins Lake Spillway and that the City should pursue legal action to be compensated for flood damages in the winter of 2007-08. Based on a review of Water Survey Canada flow records, RTA generally operates the reservoir in a manner that reduces both snowmelt and ice-related flooding. RTA has no control of the flow originating from the drainage basin below the dam, which includes the Stuart and Nautley Rivers. In the fall and winter, this lower basin contributes a relatively large portion of the flow at Prince George.

Snowmelt flows in 2007 were exceptionally high and large flow releases continued through the summer and fall. During December 2007 the following average flows were recorded:

- Skins Lake Spillway - 84 m³/s
- Nautley River - 35 m³/s
- Stuart River - 135 m³/s
- Nechako River at Isle Pierre - 259 m³/s

The three upstream flows add up to 254 m³/s which seems reasonable compared to the flow at Isle Pierre. The contribution from the reservoir was about a third of the total flow. The reported December average of 331 m³/s for Vanderhoof appears to be incorrect and may be due to gauging problems during freeze-up.

Section 4 of the Phase 1 report noted that a flow of at least 200 m³/s is necessary for ice-related flooding to occur. If almost no flow had been released at the Skins Lake spillway, perhaps flooding could have been avoided but then spring reservoir levels may have been much too high. However, without the reservoir in place, natural flows may have been substantially higher than 84 m³/s.

During the ice-related floods in 2007-08 large water level fluctuations were observed. This was not the result of RTA “playing with the tap” but was caused by sudden consolidation of the ice. These ice generated waves are called “javes” and have been observed on other rivers as well.

It is recommended that the City encourage RTA and MOE to work towards maximizing the flood mitigation potential of the reservoir. The City may wish to raise this matter through the Nechako Watershed Council and by contacting Mr. Neil Peters, Head of Flood Safety Section, MOE.

Monitoring of flows on the Nechako River is fundamental to assessing the potential severity of freeze-up. While it is difficult to estimate accurately the flows during the freeze-up period, efforts are required to improve the flow estimates at Isle Pierre. We recommend the City contact Mr. Bruce Letvak, MOE’s coordinator for Water Survey Canada (WSC) to request that WSC undertake the following:

- Provide real time water level and flow estimates on the Stuart River at Stuart Lake outlet.
- Establish a winter discharge measurement program at Isle Pierre to establish a winter rating curve that reflects the effects of a partial or complete ice cover.

Additional work to optimize the current flood routing algorithms to route flows from Cheslatta Falls during the winter period is also recommended.

There are likely enough WSC stations on the Nechako upstream of Prince George to determine flows. However, to be able to assess the ice-related water levels (and help with compiling ice-related water level data to establish forecasting protocols) it would be useful to install water level gauges within Prince George. It would be worthwhile to permanently re-establish the Cameron Street Bridge gauge, along with some temporary gauges along the

river between Cottonwood Island and Morning Place to help track the advance of the ice front, estimate ice thickness, and better characterize the ice-related surges.

Project Outline:	<ol style="list-style-type: none"> 1. NHC to describe the operational requirements for gauge installation, help with the development of winter rating curves, and work on the flood routing. 2. City of Prince George to install gauges, establish a data retrieval system and coordinate with provincial and federal agencies to improve upstream flow estimates.
Cost:	Approximately \$30,000 for gauge installation and \$40,000 to describe the operational requirements for the gauges, help with the development of winter rating curves, and work on flood routing.
Project timing:	Within next one or two years.
Importance:	High in short term and long term.

4.6 GROUNDWATER ASSESSMENT

During the ice-related flooding in 2007-08, areas within the floodplain at considerable distance from the river were flooded by seepage flows. GeoNorth (2006 and 2008) recorded the groundwater levels at a number of test sites in Area A_N (South Bank of Nechako River at Confluence). Thurber Engineering (2008) assessed groundwater along River Road and a subdrain was installed along the road. Infilled former back-channels in the area may provide concentrated seepage routes for groundwater and should be located in the field.

Groundwater problems were also observed in Area C_N, North Bank of Nechako River near Confluence; Area D_N, North Bank of Nechako River West of John Hart Bridge and Area E_N, North Bank of Nechako River at Morning Place. During high Fraser River flood levels, groundwater problems have been experienced in Area B_F, West Bank of Fraser River at South Fort George and Area D_F, West Bank of Fraser River at Lansdowne South End. If dikes are considered for any of these areas, groundwater assessments need to be undertaken to develop seepage cut-off designs, provision for internal drainage and pumping requirements.

An outline of the additional investigation required for design of the seepage control measures for Area A_N, South Bank of Nechako River at Confluence, and associated costs were provided by Thurber Engineering as follows:

Project Outline:	<ol style="list-style-type: none"> 1. Review monitoring well data obtained. 2. Conduct a site reconnaissance. 3. Conduct pump testing from the River Road subdrain manholes and pump chambers at high groundwater conditions to test soil hydraulic conductivity. 4. As necessary, expand on Geo-North monitoring program by drilling additional monitoring wells test wells (10 m depth). 5. Subject all drill hole samples to routine laboratory tests (moisture
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	<p>content and visual identification) and selected samples to gradation testing to allow estimates of soil permeability (hydraulic conductivity).</p> <p>6. Compile old and new test hole data to prepare a soil model on several sections along River Road.</p> <p>7. Analyze the groundwater regime and flows under River Road using SeepW computer program to establish the optimum seepage cut-off design.</p> <p>8. Prepare report.</p>
Cost:	\$42,500 (The cost of the data loggers is excluded on the assumption that GeoNorth's loggers can be extracted from existing monitoring wells and used in the new ones.)
Project timing:	Within next year.
Importance:	High

Similar procedures and costs are anticipated for the other groundwater problem sites if dike construction is to be undertaken.

4.7 RIVER BED MONITORING

The river bed at the confluence area needs to be monitored over time to more accurately determine how the channel changes. The 2008 grid bathymetric survey, covering the area between Fraser Cross-Sections 22 and 27 to Nechako Cross-Section 4, can be used as the baseline condition. Repeat surveys for this area are recommended at least every other year for the next four years, with subsequent adjustment to suit results obtained.

Based on comparison of 1979, 1995 and 2008 cross-sections, the Fraser and Nechako reaches within the City limits (outside the confluence area) are relatively stable. However, it is recommended that the rivers be re-surveyed and, in case major channel changes are detected, the floodplain mapping revised. Re-surveys should be done roughly every 10 to 15 years but this may need to be modified if very high flood flows occur.

Project Outline:	<p>1. NHC to conduct repeat grid surveys of the confluence area in 2010 and 2012 or optionally, following future large floods.</p> <p>2. Compare results from previous surveys and estimate volume change.</p>
Cost:	Approximately \$15,000 per confluence survey. Approximately \$60,000 for cross-sectional survey of entire project area.
Project timing:	Within next several years for confluence grid survey or 10-15 years for cross-section survey.
Importance:	Medium.

4.8 FUTURE IMPACTS ON FLOOD FLOWS (CLIMATE CHANGE, MOUNTAIN PINE BEETLE, NECHAKO RESERVOIR REGULATION)

More detailed hydrologic analysis and modelling would be required to examine how climate change and Mountain Pine Beetle infestation might change the flow regime in the Nechako and Fraser Rivers at Prince George. Results from current investigations of both factors by the Pacific Climate Impacts Consortium (PCIC) should be reviewed when available.

MOE in cooperation with Rio Tinto Alcan should be encouraged to predict likely reservoir operations during a 200-year flood, so that the reducing effect on the design flow at Prince George can be estimated. Any physical alterations to the reservoir, for example dredging of the Thatsa Narrows, could alter flow characteristics. However, the proposed new water release facility would likely have little impact on flood flows.

Project Outline:	1. NHC to follow new results from PCIC as they become available. 2. City to contact MOE and maintain active role in Nechako Watershed Council.
Cost:	Minimal
Project timing:	Over next several years.
Importance:	High

5. PROJECTS BY RISK AREA – NECHAKO RIVER

The following sections summarize input from the public consultations. Comments were received on the various flood control measures in general and also specific to the identified risk areas. The comments were reviewed and considered in recommending final flood control solutions. Based on the public's input and the Phase 1 evaluation, solutions are presented for the different areas. Flood control solutions were selected in a manner that does not increase the flood hazard or severity for other areas.

The tasks necessary to implement the projects are outlined and include additional data collection, field assessments, design, environmental permitting, construction, future maintenance requirements and project limitations. Approximate timelines are provided for the work, including estimated costs for additional investigations. Class D cost estimates from Phase 1 are included and more accurate costs will be prepared once the additional investigations have been completed. The Class D cost estimates included an engineering allowance.

The initial assessment of flood control options along Nechako River from Phase 1 was as summarized on the next page:

Risk Area/Option	Priority	Cost Ratio	Capital Cost (\$M)	Environ. Impact	Ranking
Area A_N - South Bank of Nechako River at Confluence	1				
No Protection		1.00		L	5
River Dike		1.54	17.0	H	4
Setback Dike - River Side of River Road		1.64	15.5	M	1
Setback Dike - Along Railway		1.58	8.5	L	3
Land Use Change		1.60	23.2	L	2
Area B_N - North Bank of Nechako River East of John Hart Bridge	4				
No Protection		1.00		L	1
River Dike - Full Height		0.98	3.5	H	n/a
Platform for Temporary Protection		0.88	2.7	H	2
Raise McAloney and Ongman Roads		0.77	3.9	M	3
Land Use Change		0.52	8.8	L	4
Area C_N - North Bank of Nechako River Near Confluence	2				
No Protection		1.00		L	2
River Dike		0.73	10.1	H	n/a
Ring Dike		-	3.4	H	n/a
Land Use Change and Floodproofing		0.88	9.3	L	1
Area D_N - North Bank of Nechako River west of John Hart Bridge	3				
No Protection		1.00		L	2
River Dike - Full Height		1.12	3.3	H	n/a
Platform for Temporary Protection		0.95	2.6	H	3
Raise Preston Road		1.13	1.2	M	1
Land Use Change		0.76	6.7	L	4
Area E_N - North Bank of Nechako River at Morning Place	6				
No Protection		1.00		L	2
River Dike- Full Height		1.06	2.1	H	n/a
Platform for Temporary Protection		0.93	1.6	H	3
Land Use Change and Floodproofing		2.05	1.4	L	1
General					
Enlarge Cottonwood Island Sidechannel			3.0	H	1
Restore Historic Backchannel - Area A _N			9.0	H	3
Construct Sidechannel - Area C _N			7.6	H	2

The highest ranked solutions, with a ranking of “1”, were put forward as the preliminary flood control solutions during the public consultations. However, all options were open to discussion.

5.1 AREA A_N – SOUTH BANK AT CONFLUENCE

The area is at risk of flooding from Nechako River during the winter and from the Fraser River during the spring–summer. The Phase 1 highest ranked solution is construction of a setback dike on the river side of River Road.

During the public consultations, property owners outside the proposed setback dike were not satisfied with the proposed solution and suggested land-use change over the entire area. However, the area is almost 300 ha and includes a portion of the downtown core as well as the rail-yard, which makes land-use change over the entire area very costly. There is relatively limited development outside the proposed dike and introducing land-use change in this small area is more cost effective. A dike next to the river, would protect this development as well but in addition to having a large environmental impact would constrain the floodway somewhat, require extensive erosion protection and over the long-term expensive maintenance. The footprint of the dike would be 15-20 m wide and if placed next to the river, would have significant impact on the riverside development and require land acquisition.

A setback dike on the river side of River Road is considered the most viable solution. The crest elevation will be determined based on the 200-year flood level plus a freeboard allowance. The side slopes will typically be about 2H: 1V. The crest will be wide enough to accommodate maintenance equipment. As proposed, the dike will be set-back from the river and placed along the road corridor or in locations that cause least interference with other land users such as the Railway Museum.

Dikes can fail by either overtopping or a combination of erosion, slumping or seepage. MOE recommends that any new development be built to FCL's even in areas that are protected by dikes. The primary objective of the dike is to reduce flood damage to the existing development, not to facilitate extensive development in the future. Any new development within the area should be restricted or raised to FCL's.

Groundwater seepage has been identified as a problem and the diking must include adequate seepage prevention. Internal drainage provision and pumping must also be provided.

There may be some minor riparian area encroachment and consultations with DFO are foreseen along with potential for BC Environmental Assessment Act review.

Project Outline:	<ol style="list-style-type: none"> 1. Using the completed floodplain topographic base-maps, establish existing ground elevations. Determine railroad elevations at upstream end of area. 2. Determine dike crest elevations based on floodplain maps and selected freeboard. 3. Assess seepage prevention and groundwater drainage/pumping requirements. 4. Develop a conceptual dike design. Evaluate material volumes and prepare Class C cost estimates.
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	<ol style="list-style-type: none"> 5. Apply for environmental permitting. Develop mitigation and compensation requirements. Determine optimum construction window. Prepare construction schedule. 6. Determine which properties will be affected by the dike footprint, develop and implement a land-use change plan. Discuss layout with Railroad Museum and other landowners. 7. Develop a preliminary dike design, prepare Class B cost estimates and obtain approval from MOE. 8. Apply for funding. 9. Finalize design, prepare tender documents and Class A cost estimates and proceed with construction. 10. Prepare as-built drawings and Operation & Maintenance Manual. 11. Implement maintenance program with annual reporting. 12. Restrict or regulate future development.
Total Cost:	\$300,000 for engineering. Class D project cost estimate: \$15.5M.
Project timing:	1 year to start of project, 3 years to complete.
Importance:	High

5.2 AREA B_N – NORTH BANK EAST OF JOHN HART BRIDGE

Winter flooding is the more severe flood condition but high water levels can also be experienced in the spring-summer. During the public consultations, no participants attended the discussions specific to Area B_N. The option of not providing any form of permanent protection rated the highest in the initial assessment. The second highest ranking option involved providing a platform for constructing temporary protection when needed.

The area contains about a dozen commercial and light industrial buildings, generally with slab on grade construction. It has not been confirmed that floor levels are below FCL's and therefore it is recommended that a survey of existing floor levels be completed to assess the flood damage potential. Even if no formal protection is introduced, building owners may still prefer to modify services and general arrangements to reduce future flood damage.

The area includes an arterial road, North Nechako Road, which was flooded and impassable during the 1996 ice-related flood. Other City infrastructure includes a major sewage lift station (PW117), a back-up water well and a water booster pump station.

Prior to the public consultations in June of 2009, the team was made aware that property owners in this area have been concerned about the remnants of temporary floodproofing berms on their property. If the decision is made to have no formal protection, the City may wish to consider complete removal of these works to prevent future liability and encroachment issues.

Project Outline:	1. Survey floor elevations and prepare an infrastructure inventory. 2. Restrict future development. 3. Inform building owners and/or occupants of revised 200-year flood elevations and FCL's in their location.
Cost:	\$25,000 not including temporary berm removal.
Project timing:	1-3 years
Importance:	Medium

5.3 AREA C_N – NORTH BANK NEAR CONFLUENCE

The area is at risk of flooding from Nechako River during the winter and from the Fraser River during the spring–summer. In the Phase 1 evaluation, the highest ranking solution was land-use change in the area south of PG Pulpmill Road and local floodproofing as required on the north side.

Several residents were directly impacted by the ice-related flooding in 2007-08 and actively participated in the public consultations. Questions and comments mainly related to how land-use change would be implemented, what specific floodproofing measures should be considered and the present condition of the PG Pulpmill Road embankment.

5.3.1 LAND-USE CHANGE

Some buildings south of PG Pulpmill Road were extensively damaged and according to some residents, inadequate compensation was received from the provincial government. In this location, land-use change was considered to be the most cost-effective and least-maintenance solution. An inventory of the existing development needs to be completed and floor elevations surveyed to confirm the need and extent of land-use change. The deep/fast water diagram in Figure 2.1 will be used for guidance. The method by which the land-use change is introduced will be determined jointly by the City and the owners. Typically, gradual implementation is adopted, whereby properties are acquired over time as owners wish to vacate. New development on the acquired properties, as well as in the general area, should be restricted.

5.3.2 PG PULPMILL ROAD

Based on the available survey information, the PG Pulpmill Road crest elevation is above the revised FCL and would be high enough to serve as a dike. However, the embankment material is unsuitable for diking and the road does not act as a dike. This may have been unclear from the diagram in the Phase 1 report. According to a recent investigation by City staff, four culverts run through the embankment and during high Nechako water levels, back-flow occurs. The culverts need to be inventoried and if feasible, gates installed to prevent back-flow. The need for pumping local inflows while gates are closed should also be

evaluated. It would not be cost-effective to provide seepage prevention along the length of the road and convert it to a dike. The road provides an important emergency access route.

5.3.3 LOCAL FLOODPROOFING

The area north of PG Pulpmill Road is low-lying and experienced flooding in 2007-08 from groundwater seepage and culvert back-flow. An inventory of the existing buildings needs to be compiled and floor elevations surveyed.

General floodproofing guidelines for British Columbia have been provided by Fraser Basin Council (undated) and Ministry of Environment (1981, 2007). The US Army Corps of Engineers' National Flood Proofing Committee (NFPC) defines floodproofing as "any combination of structural or non-structural changes or adjustments incorporated in the design, construction, or alteration of individual structures or properties that will reduce flood damages". Flood proofing measures are generally effective in reducing damage from the design flood but if flood levels exceed design conditions, damage equal to or greater than without any floodproofing may occur. Basic floodproofing methods are:

- Raise buildings and support them on fill, piers, piles, columns or bearing walls.
- Provide watertight sealants to low-lying building spaces (dry floodproofing).
- Use construction that does not sustain damage even if wetted (wet floodproofing).

Appendix B contains a description of floodproofing measures by NFPC. In addition to structural modifications, building services such as water, electricity, gas and septic fields also need to be modified to withstand flooding. In the PG Pulpmill Road area all of the properties are serviced by onsite water and sewer systems. These systems must be assessed and modified to operate or at least be able to withstand flood conditions without damage or unsafe health consequences.

It should be noted that one house on the south side of PG Pulpmill Road was floodproofed by the owners but that damage was sustained, not during the flood but during the recession of the flood waters which caused consolidation of the earth fill used to raise the concrete slabs. This underlies the importance of proper design and construction of flood proofing works.

Project Outline:	<ol style="list-style-type: none"> 1. Compile inventory of infrastructure (culverts) and buildings including surveyed floor elevations (north and south of road). 2. Determine land-use change requirements and develop time-frame for implementing the changes. 3. Design and install culvert gates. 4. Evaluate need for pumping local inflows when culvert gates are closed. 5. Develop flood proofing recommendations for individual buildings.
Cost:	\$50,000; \$9.3M for land-use change.
Project timing:	1 year
Importance:	High

5.4 AREA D_N – NORTH BANK WEST OF JOHN HART BRIDGE

The main threat of flooding is ice-related events on the Nechako River. The solution that ranked highest in Phase 1 was to raise Preston Road, incorporate seepage prevention, and provide either local floodproofing or introduce land-use change on the river side of the road. With the revised design profile, the 200-year flood boundary will likely shift to about 50 m north of North Nechako Road, increasing the number of houses within the floodplain. Over the sixty year record period, a flood of this magnitude has not occurred. An inventory of structures and floor elevations is required. A school is located in the area.

Some residents, particularly within the Del Haven housing development were affected by the ice-related flooding in 2007-08 by groundwater entering basements. The development is within an active floodplain area and is partly located on a filled-in backchannel and sits on highly porous material. Raising attached-unit housing is not practical and dry floodproofing would be very difficult. Wet floodproofing may be a solution during medium-high flood events. Groundwater pumping, considered during the winter of 2007-08, could remove fine soils and result in settlement of buildings. Installing an impermeable cut-off to reduce seepage flows would be difficult and would not be helpful at the design flood level when surface flooding occurs. Future development should be restricted where it cannot be constructed above the revised FCL.

A number of residents from this area took part in the public consultations. In general, turning Preston Road into a dike was not favoured. It is not clear if this opinion was expressed by residents on the river or land side of the road. Residents on the river side would naturally not benefit from having the road raised. Since only extreme floods would cause flooding on the landside of Preston Road, residents in this area may not realize they are at risk. High groundwater is known to be a problem and for Preston Road to serve as a dike, seepage prevention must be provided along with adequate drainage and pumping. A survey of road crest elevations and an inventory of existing culverts are required. If residents of the entire area are opposed to raising Preston Road, providing no protection and dealing with flooding as it occurs received the second highest ranking in this area.

<p>Project Outline:</p>	<ol style="list-style-type: none"> 1. Compile an inventory of development within the revised floodplain area, including floor elevations and road crest elevations. 2. Determine amount Preston Road would need to be raised and assess seepage prevention, drainage and pumping requirements. 3. Inform residents/building owners of revised flood boundary and determine if public on landside of road are in favour of having road raised and verify that this is a cost effective solution. 4. If yes, develop a conceptual road dike design. 5. Obtain MOE approval. 6. Evaluate material volumes and prepare Class B cost estimates. 7. Apply for environmental permitting. Develop mitigation and compensation requirements if required. Determine optimum
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	<p>construction window. Prepare construction schedule.</p> <p>8. Apply for funding.</p> <p>9. Finalize design, prepare tender documents and proceed with construction.</p> <p>10. Prepare as-built drawings and Operation & Maintenance Manual.</p> <p>11. Implement maintenance program.</p> <p>12. Restrict future development.</p>
Cost:	\$100,000 for engineering; Class D project cost estimate: \$4 M.
Project timing:	1-3 years
Importance:	High

5.5 AREA E_N – NORTH BANK AT MORNING PLACE

The area was affected by flooding during the winter 2007-08, largely by groundwater seepage, and a number of residents took part in the public consultations. Winter flooding is the main threat and the mitigation recommended in Phase 1 was a combination of land-use change and local floodproofing. A common concern expressed during the consultations was that the recommended options were not specific enough. However, in order to provide specific recommendations, the floodplain maps need to be updated and a building inventory prepared listing surveyed floor elevations.

The increases in FCL's from the 1997 floodplain mapping are large in this reach (1 m to 1.5 m) and since the ground is relatively flat, flood inundation boundaries are expected to shift by up to 60 m inland. The approximate floodway zone (Figure 2.1) should be outlined and used for assessing approximate land-use change requirements. Present asset value estimates of \$1.9 M were based on the 1997 floodplain maps. The value may increase to as much as \$3.4 M when the mapping is updated.

Temporary flood protection in the form of gabion diking was installed in 2007-08. During the consultations there were some complaints of inadequate clean-up following the flood, highlighting a drawback of temporary protection. However, the residents appreciate their river views and do not wish to relocate or have permanent diking installed. They generally approve of temporary protection as needed and are willing to provide river access for City crews.

Project Outline:	<ol style="list-style-type: none"> 1. Compile building inventory and survey floor elevations. 2. Assess detailed floodproofing needs and discuss with owners. 3. If land-use change or floodproofing is impractical or not wanted, plan for temporary protection. 4. Restrict future development or implement long-term voluntary land-use change plan.
Cost:	\$15,000 for engineering; Class D estimate: \$1.4 M
Project timing:	1 year
Importance:	Medium

5.6 AREA F_N – SOUTH BANK AT FOOT HILLS BRIDGE

The area contains a water-well and pump station that supplies the City but is otherwise largely undeveloped. Critical infrastructure elevations should be compared with the revised FCL's and the need for any potential mitigation assessed.

Further development should be restricted.

Project Outline:	1. Identify critical infrastructure elevations. 2. Assess need for mitigation. 3. Restrict new development.
Cost:	\$5,000
Project timing:	1 year
Importance:	High

5.7 AREA G_N – SOUTH BANK BETWEEN JOHN HART AND FOOTHILLS BRIDGES

The area contains a water-well and pump station that supplies the City but is otherwise largely undeveloped. The two wells in Areas F_N and G_N supply over 80% of the City's water. The well in Area G_N was inundated in 1996 and to prevent contamination in 2007 it was shut down. Critical infrastructure elevations should be compared with the revised FCL's and the need for any potential mitigation assessed.

Further development should be restricted.

Project Outline:	1. Identify critical infrastructure elevations. 2. Assess need for mitigation. 3. Restrict new development.
Cost:	\$5,000
Project timing:	1 year
Importance:	High

5.8 GENERAL – COTTONWOOD ISLAND SIDE CHANNEL

Section 4 of the Phase 1 report discussed ice and gravel removals. Our ice-specialist clarified this further during the public meetings, yet there were requests for clearer explanations. At this point, probably the only way to illustrate this more clearly would be by building a physical model of the rivers in the NHC hydraulic laboratory. However, this is not within the current budget.

FCL's in the Lower Nechako River near the confluence are set by freshet flooding (backwater from the Fraser River) and would not be altered by the side channel capacity increase. However, increasing the flow capacity of Cottonwood Island side channel was identified as a means of reducing ice-related flood levels downstream of the side channel entrance. The channel would only be effective as long as it remains ice-free and an inlet structure is necessary to prevent ice floes from entering the channel, either in the form of a rock weir with gated culverts or a simpler structure with guiding trash-racks. There is sufficient gradient for the water to find its way into the Fraser, a concern raised during the consultations. The channel improvements would require extensive environmental permitting (Fisheries Act authorization, BC Environmental Assessment Act review, Canadian Environmental Assessment Act review and Water Act approval) but would also provide an opportunity to improve habitat by ensuring year round flow and improved oxygen levels. Enhancing the recreational value of the area would be another benefit and the public generally favoured this project.

Previously, an environmental application to remove a gravel bar at the downstream end of the channel was prepared by the consulting team but the work has not yet proceeded. The gravel removal formed part of the first phase of a two-phased project. Also included in the first phase were engineering of the channel and entrance structure, as well as environmental work. The proposed second phase involved the construction of the channel.

There is potential for opening up other filled-in back-channels in the area. The work would be expensive and require extensive environmental permitting but was favoured by the public and the City may wish to consider these projects in the long-term.

Project Outline:	<p>Phase 1:</p> <ol style="list-style-type: none"> 1. Remove gravel from side-channel outlet. 2. Survey side channel thalweg profile and obtain additional cross-sections. 3. Prepare channel and intake design. 4. Prepare construction schedule. 5. Prepare permit applications. 6. Prepare funding applications. <p>Phase 2:</p> <ol style="list-style-type: none"> 7. Prepare tender documents and proceed with construction. 8. Prepare operation and maintenance manual.
Cost:	Phase 1: \$390,000; Phase 2: Class D cost estimate – \$3.5 M
Project timing:	1-3 years
Importance:	Medium

6. PROJECTS BY RISK AREA – FRASER RIVER

The following sections discuss the risk areas along the Fraser River and outline specific projects for protecting the areas, taking into consideration the public input received. The different steps necessary for undertaking the projects are listed. The Fraser risk areas are unaffected by ice-related flooding on the Nechako and the main flood threat is Fraser freshet flooding.

The initial assessment of flood control options along Fraser River from Phase 1 is as summarized:

Risk Area/Option	Priority	Cost Ratio	Capital Cost (\$M)	Environ. Impact	Ranking
Area A_F - Fraser River West Bank at Yellowhead Highway					
No Protection		1.00		L	1
River Dike - Full Height		0.79	1.5	H	3
Platform for Temporary Protection		0.96	0.8	H	2
Land Use Change		0.58	2.5	L	4
Area B_F - Fraser River at South Fort George	5				
No Protection		1.00		L	2
River Dike - Full Height		1.03	2.9	H	4
Platform for Temporary Protection		1.07	1.5	H	3
Land Use Change		2.46	1.4	L	1
Area D_F - Fraser River at Lansdowne South End	7				
No Protection		1.00		L	2
River Dike - Full Height		0.76	1.6	H	4
Platform for Temporary Protection		1.03	0.7	H	3
Land Use Change		1.68	0.8	L	1
Area F_F - Fraser River at Northwood Pulpmill Road					
No Protection		-		L	-
Raise Landooz Road for access		-	5.8	M	-

6.1 AREA A_F – WEST BANK AT YELLOWHEAD HIGHWAY

The FCL's in the area are roughly 0.3 m higher than the 1997 levels and will result in only a small increase of the floodplain area. If any housing falls within the revised floodplain, floor elevations should be surveyed. A storm outfall, sanitary sewer force-main and a gravity sewer are located in the area. Further development should be restricted.

Across the river, on the east bank of the Fraser River at the confluence, the 1997 floodplain boundary was drawn on the riverside of existing development. It should be confirmed that this development remains outside the flood boundary of the revised mapping.

Project Outline:	<ol style="list-style-type: none"> 1. Review extent of revised floodplain. 2. Survey floor elevations if necessary and review potential for flood damage. 3. Restrict future development.
Cost:	\$5,000
Project timing:	1-3 years
Importance:	Medium-Low

6.2 AREA B_F – WEST BANK AT SOUTH FORT GEORGE

The area was partly inundated during the spring flood of 2007, estimated to have a return period of 20 years. A number of houses and mobile homes are located within the 1997 floodplain and an inventory of houses including floor, basement, crawlspace and mobile home pad elevations is required. The extent of the floodplain will likely increase only slightly. Two storm sewer trunk lines and a sewage lift station are located in the area.

The residents that attended the public consultation sessions did not favour diking and generally agreed that local floodproofing was preferable. They stated that only a few houses have been affected by recent floods; however, the number will increase for the updated 200-year design standard. There has not been a Fraser River flood close to the 200-year level since 1936 (it was exceeded in 1894).

The highest ranking Phase 1 solution was land-use change and local floodproofing. Based on the new topographic mapping, the 200-year flood depth at each house will be evaluated and the diagram in Figure 2.1 used as a guide to determine which areas fall within the floodway (deep/fast water) and would consequently be recommended for land-use change. Any further development of the area should be restricted.

For the housing in the flood fringe zone recommended for floodproofing, building services such as water, sewage, electricity and gas also need to be modified to withstand flooding in addition to the structural modifications.

Project Outline:	<ol style="list-style-type: none"> 1. Prepare an inventory of housing within the floodplain and survey floor elevations. 2. Identify which houses fall within the 200-year floodway and should be relocated or removed. 3. Outline floodproofing measures for housing in the flood fringe zone. 4. Check elevations of access/egress routes for houses that remain. 5. Inform/discuss with residents/owners. 6. Restrict further development.
Cost:	\$20,000 for engineering; Class D cost estimate: \$2.9 M
Project timing:	1 year
Importance:	High

6.3 AREA C_F – WEST BANK AT HUDSON’S BAY SLOUGH WEST OF QUEENSWAY

Queensway acts as a standard dike and a pump station is provided for internal drainage. The road crest elevation should be compared against revised FCL’s and the pump capacity verified to determine if any improvements are required. The present development includes about 160 residential properties, some apartment buildings and a trailer park. An elementary school, a church, a major BC Hydro substation, a commercial property and ball park are also located in the area. Further development should be reviewed in terms of flood risks.

Project Outline:	1. Survey Queensway top-of-road elevation. 2. Determine drainage flows and compare with pump capacity. 3. Assess seepage. 4. City to control future development.
Cost:	\$10,000
Project timing:	1 year
Importance:	High

6.4 AREA D_F – WEST BANK AT LANSDOWNE SOUTH END

Only a few houses are located within the floodplain and land-use change or local floodproofing was recommended in Phase 1. An inventory of housing within the revised floodplain and a summary of floor elevations should be prepared. Future development should be restricted.

According to public perception flooding is not a problem at Wiens Road and only one house has been affected by flooding. However, during the 200-year design flood more extensive damage is expected. Strong opposition was expressed towards diking and raising affected housing is the preferred alternative.

A sewage treatment plant is located at the boundary of the risk area and critical elevations should be verified.

Project Outline:	1. Prepare inventory of housing, floor and road elevations and other infrastructure in the floodplain. 2. Finalize mitigation measures. 3. Inform/ discuss with residents/owners. 4. City to restrict future development.
Cost:	\$5,000 for engineering; Class D cost estimate: \$0.8 M
Project timing:	3 years
Importance:	Medium

6.5 AREA E_F – WEST BANK AT ISLAND UPSTREAM OF CONFLUENCE

This area consists of agricultural land with a barn at its northeast corner. It should be confirmed that no other buildings fall within the revised flood boundary. Future development should be restricted.

Project Outline:	1. Confirm that no residential buildings fall within the floodplain. 2. City to restrict future development.
Cost:	None
Project timing:	1 year
Importance:	Low

6.6 AREA F_F – WEST BANK AT NORTHWOOD PULPMILL ROAD

The area surrounds the Northwood Pulpmill complex, which lies on fairly high ground, mainly above 200-year FCL's. It contains parts of the Northwood Pulp Road, several private paved and gravel roads, a private bridge crossing, log storage areas and some treatment lagoons for the plant site. Landooz Road passes through the area and is the sole access for several low-density residential properties in the northeast corner of the city, as well as the North Shelley community outside the City Limits.

No participants attended the discussion table for this area during the public consultations.

Project Outline:	1. Confirm extent of revised floodplain and check for at-risk infrastructure. 2. Inform Northwood of revised FCL's. 3. Using base maps, confirm if there is a need to raise Landooz Road and by how much. 4. City to restrict/control future land development in floodplain.
Cost:	\$5,000 for pre-design engineering; Class D estimate \$5.8 M
Project timing:	3 years
Importance:	Medium

6.7 AREA G_F – WEST BANK ACROSS FROM SHELLEY

Land in the area is either undeveloped or agricultural. A natural gas transmission main traverses the area to a crossing structure over the Fraser River. Development of the floodplain area should be restricted.

To confirm the computed flood profile at the upstream end of the Fraser hydraulic model, the reference elevation of the WSC gauge at Shelley should be checked.

No participants attended the discussion table for this area during the public consultations.

Project Outline:	1. City to restrict future land development in floodplain. 2. WSC should be asked to confirm the benchmark elevation for Station 08KB001, Fraser River at Shelley.
Cost:	None
Project timing:	1 year
Importance:	Medium

7. PRIORITIZATION OF PROJECTS

The City has limited funding for implementing flood control solutions and the various projects identified in Sections 4 and 5 must be undertaken in order of priority. Several of the general projects discussed in Section 4 will need to be completed before the specific risk area projects can be undertaken.

During the public consultations, fairness in the prioritization process was requested, suggesting decisions should not merely be based on population density, damage severity and property values. The need for having an ombudsman take part in the process was highlighted. The following sections set priorities based simply on engineering considerations. The City is encouraged to review these priorities and revise them as necessary to also account for non-engineering considerations.

7.1 PRIORITIZATION OF GENERAL PROJECTS

The general projects (Section 4) need to be carried out in a logical sequence since tasks typically build on results from previous projects. The City is in the process of completing topographic base-maps for the entire City and this will constitute the key input for several of the projects. It is recommended that the tasks be undertaken in the order listed below.

Order	Project	Cost	Timing	Importance
1	Freeboard selection	Minimal	Immediate	High
2	Revise floodplain maps and City's floodplain regulation bylaw	\$20,000	Immediate	High
3	Groundwater assessment – Install pump- test well and level gauges for Area A _N	\$42,500	1 year	High
4	Erosion hazard maps	\$25,000	1 year	High
5	Install water-level gauges & develop winter flow monitoring program	\$70,000	1-2 years	High
6	Ice-related flood forecasts and public notification policy	\$20,000	2-3 years	High (long term)
7	Freshet forecasting	\$25,000	1 year	Medium - High
8	River bed monitoring	\$15,000/survey	2-3 years	Medium
9	Future impacts on flood flows	Minimal	2-5 years	High
	TOTAL:	\$217,500		

7.2 PRIORITIZATION OF RISK AREA PROJECTS

Completing the freeboard, floodplain mapping, groundwater and erosion assessments is recommended before the specific risk area projects are started. The other general projects can be carried out concurrently with the risk area projects.

There are a number of criteria to consider in prioritizing the risk areas:

- Combined probability of flooding. If an area is equally at risk of flooding from either the 200 year freshet flood on the Fraser or the 200 year ice-related flood on the Nechako, the actual return period is considerably less than 200 years. This return period is difficult to estimate as the two flood events are statistically somewhat dependent. The record snow-pack in the spring of 2007 may have partly increased the winter flows in 2007-08 as a result of groundwater saturation and high initial reservoir levels.
- The extent of damage caused by the 200-year flood. A low-lying area exposed to deep water during the 200-year flood will naturally sustain more damage than an area inundated by only a small amount. Low-lying areas are also prone to more frequent flooding and may sustain extensive damage at lesser return period events.
- The suddenness of flooding. If floodwaters rise relatively slowly or can be reasonably well predicted, there is more time for temporary protection, emergency evacuations and less risk of loss of life. Both the Fraser freshet and Nechako ice-related flooding can be forecasted to some extent. During ice consolidation, relatively large water level fluctuations may occur, increasing the flood hazard along the Nechako.
- The duration of flooding. If high flood waters last for prolonged periods more extensive damage will occur compared to a shorter duration flood. Even though the Fraser freshet peak may last for a week or more, Nechako ice-related flooding may go on for even longer periods.
- The presence of ice and occurrence of freezing temperatures. Freezing flood waters and the accumulation of ice are likely to result in more extensive damage and more difficult emergency access/egress.
- The potential number of houses, businesses and other infrastructure affected by the flooding. In terms of reducing the cost of damage compensation, areas with the highest damage potential need flood protection most urgently. Residential housing may rate higher than commercial/industrial development. Maintaining regional transportation corridors is vital to the community as well as for emergency access/egress to specific areas. Protecting large land areas would have a higher priority than protecting small areas. Damage to water supply, waste water, electrical, gas and communication systems need to be taken into account. When infrastructure, such as hospitals/schools or hydro/water wells/railways/highways are impacted a large number of people outside the flooded areas are affected resulting in a more critical ranking.

- The cost effectiveness of a particular flood control solution. If substantial protection can be obtained at a relatively low cost, the area warrants a higher priority rating than an area of similar value that is relatively more expensive to protect.
- Erosion hazards. Bank erosion can be gradual, occurring over many years, or sudden as a result of a river avulsion during a large flood. The main concern of the present project is flood protection. However, potential erosion sites were identified that may require mitigation and should be considered in the project priority setting once the erosion hazard mapping has been completed.

In order to provide the City with a guide for selecting the order to implement the different risk area projects, the above evaluation criteria were assembled in a matrix and given weighting factors to reflect their relative importance. A similar approach was previously adopted in Progress Report 1 (NHC et al, 2008) to carry out an initial screening of various flood control solutions.

The table below summarizes the criteria adopted and shows the values for the various rankings of high, medium and low.

Criteria	High Rank (1)	Medium Rank (2)	Low Rank (3)
Flood Occurrence	Winter + Spring	Winter only	Spring only
Water Depth	>1 m	0.5 to 1 m	<0.5 m
Duration\ Warning	Long / sudden fluctuations	Medium / minor fluctuations	Short / no fluctuations
Number of Buildings	>25	10 to 25	<10
Infrastructure Impact	Large number of people outside flooded area affected	Some people outside flooded area affected	Only local residents affected
Asset Value	>\$25 M	\$3 M to 25 M	<\$3 M
Protected Area	>50 ha	4 to 50 ha	<4 ha
Cost Effectiveness = Total Asset Value / Capital Cost of Protection	>2	1 to 2	<1

Numeric values and rankings for each risk area are summarized in Table 7.1.

In the evaluation matrix shown in Table 7.2, the high, medium and low rankings were assigned values of respectively 1, 2 and 3. The individual criteria are not all equally important and to compensate for this, weights were assigned, with the most important criteria receiving the highest weighting. The 'Flood Occurrence', 'Number of Buildings', 'Infrastructure Impact' and 'Asset Value' factors were most heavily weighted at a value of 3. The 'Water Depth' and 'Cost Effectiveness' received a weighting of 2 and 'Duration/Warning' and 'Area Protected' were weighted at a value of 1.

By multiplying the ranking index by the weighting, the various risk areas were ranked as listed in Table 7.2. The matrix provides a simplified approach for evaluating the relative importance of protecting the various areas and forms a guide for selecting projects.

The risk areas are summarized in order of priority on the next page, including costs of additional investigations and Phase 1 Class D cost estimates. It should be noted that the Class D costs are preliminary estimates and that they include an allowance for engineering. The Class D costs will need revision once the additional investigations have been completed.

Order	Risk Area	Engineering Cost \$	Capital Cost \$	Timing	Importance
1	Area A _N – Nechako South Bank at Confluence	\$300,000	\$15.5 M	1-3 years	High
2	Area C _F – Fraser West Bank at Hudson's Bay Slough West of Queensway	\$10,000	-	1 year	High
3	Area C _N – Nechako North Bank near Confluence	\$50,000	\$9.3 M	1 year	High
4	Area D _N – Nechako North Bank West of John Hart Brdg	\$100,000	\$4 M	1-3 years	High
5	Area B _F – Fraser West Bank at South Fort George	\$20,000	\$2.9 M	1 year	High
6	Area B _N – Nechako North Bank East of John Hart Brdg	\$25,000	-	1 -3 years	Medium
7	Area E _N – Nechako North Bank at Morning Place	\$15,000	\$1.4 M	1year	Medium
8	Area D _F – Fraser West Bank at Lansdowne South End	\$5,000	\$0.8 M	3 years	Medium
9	Area G _N – Nechako South Bank between John Hart and Foothills Bridges	\$5,000	-	1 year	High
10	Area F _N – Nechako South Bank at Foot Hills Bridge	\$5,000	-	1 year	High
11	Area F _F – Fraser West Bank at Northwood Pulpmill Road	\$5,000	\$5.8 M	3 years	Medium
12	Area G _F – Fraser West Bank across from Shelley	\$0	-	1 year	Medium
13	Area A _F – Fraser West Bank at Yellowhead Highway	\$5,000	-	1-3 years	Medium-Low
14	Area E _F – Fraser West Bank at Island upstream of Confluence	\$0	-	1 year	Low
	TOTAL:	\$545,000	\$39.7 M		

Enlarging the Cottonwood Island side channel was identified as a beneficial project even though it would not protect against freshet flooding which determines the FCL's in the area. It is therefore not possible to prioritize this project against the others using the matrix approach and the City needs to determine the timing of the work based on non-engineering considerations. The estimated Phase 1 cost (bar removal, engineering and environmental work) is \$390,000 and the Phase 2 construction cost \$3.5M.

Table 7.1: Area Ranking

RISK AREA	1. Flood Occurrence	Flood Occur. Ranking	2. Water Depth Approx Avg (m)	Water Depth Ranking	3. Flood Warning	Warning Ranking	4. No of Buildings	Building Ranking	5. Impact on Infrastructure	Infrastr. Ranking	6. Asset Value M (\$)	Asset Value Ranking	7. Protected Area (ha)	Protected Area Ranking	Protection Cost (\$)	8. Cost Effectiveness	Cost Effectiveness Ranking
Nechako River:																	
Area A _N – South Bank at Confluence	Winter+Summer	High	0.4 to 1.2	Deep	Fluctuations	1	166	Many	CN Rail	High	300	High	298.2	Large	15.5	19.4	High
Area B _N – North Bank east of John Hart Bridge	Winter	Med	0.6	Med	Fluctuations	1	22	Med	City infrastr	Med	14.3	Med	9.7	Med	1	1.0	Med
Area C _N – North Bank near Confluence	Winter+Summer	High	0.8 to 1.3	Deep	Fluctuations	1	41	Many	Local only	Low	9.8	Med	89.5	Large	9.3	1.1	High
Area D _N – North Bank west of John Hart Bridge	Winter	Med	0.8 to 1.5	Deep	Fluctuations	1	35	Many	School	Med	18.4	Med	7.9	Med	4	4.6	Med
Area E _N – North Bank at Morning Place	Winter	Med	0 to 0.7	Med	Fluctuations	1	8	Few	Local only	Low	1.9	Low	4	Small	1.4	1.4	Med
Area F _N – South Bank at Foot Hills Bridge	Winter	Med	2.4	Deep	Fluctuations	1	1	Few	City well	High	<1	Low	-	Med	0	-	Low or None
Area G _N – South Bank between John Hart and Foothills Bridges	Winter	Med	1.9	Deep	Fluctuations	1	1	Few	City well	High	<1	Low	-	Med	0	-	Low or None
Fraser River:																	
Area A _F – West Bank at Yellowhead Highway	Summer	Low	1.5	Deep	Little fluct.	2	0?	Few	Local only	Low	2.3	Low	-	Small	0	-	Low or None
Area B _F – West Bank at South Fort George	Summer	Low	1.4	Deep	Little fluct.	2	29	Many	Sewage Lift	Med	4.9	Med	4.5	Med	2.9	1.7	Med
Area C _F – West Bank at Hudson's Bay Slough W of Queensw.	Summer	Low	0.2 to 4.2	Deep	Little fluct.	2	165	Many	School/St./Hydro	High	75	High	87	Large	0	-	High
Area D _F – West Bank at Lansdowne South End	Summer	Low	0.1	Shallow	Little fluct.	2	3	Few	Treatm. Plant	High	1.2	Low	1.7	Small	0.8	1.5	Med
Area E _F – West Bank at Island upstream of Confluence	Summer	Low	0.2	Shallow	Little fluct.	2	1	Few	Local only	Low	<1	Low	-	Small	0	-	Low or None
Area F _F – West Bank at Northwood Pulpmill Road	Summer	Low	0.6 to 1.4	Deep	Little fluct.	2	10	Med	Road	Med	3.7	Med	-	Large	5.8	0.6	Low
Area G _F – West Bank across from Shelley	Summer	Low	0.8 to 4.0	Deep	Little fluct.	2	4	Few	Local only	Low	<1	Low	-	Med	0	-	Low or None

Notes:

1. High(1) =Flooding may occur in winter and spring. Medium(2)=Winter flooding with ice and freezing temperatures. Low(3)=Spring flooding.
2. Deep(1)=Average depth>1m. Medium(2)=Average depth approx 0.5m. Shallow(3)=<0.5m.
3. High(1)=Long duration/sudden fluctuations. Medium(2)=Medium duration/little fluctuation. Low(3)=Short duration/no fluctuation.
4. High(1)>25. Medium(2)= 10 to 25. Low(3)<10.
5. High(1)=Critical infrastructure affecting a large number of people. Medium(2)=Some people outside direct area affected. Low(3)=Only local residents are affected.
6. High(1)>\$25M. Medium(2)= \$3M to 25M. Low(3)<=\$3M.
7. Large(1)>50 ha. Medium(1)=4 to 50 ha. Small(1)<4ha.
8. Cost Effectiveness Ratio High(1)>2. Medium(2)=1 to 2. Low(3)<1.0.

Table 7.2: Priority Matrix RISK AREA	EVALUATION CRITERIA								WEIGHTING FACTOR 1 = less important 3 = more important								Total Weight Factor	Area Priority Ranking
	Flood Occurrence ¹	Water Depth ²	Duration/Warning ³	Number of Buildings ⁴	Infrastructure Impact ⁵	Asset Value ⁶	Area Protected ⁷	Cost Effectiveness ⁸	Flood Occurrence ¹	Water Depth ²	Duration/Warning ³	Number of Buildings ⁴	Infrastructure Impact ⁵	Asset Value ⁶	Area Protected ⁷	Cost Effectiveness ⁸		
	3	2	1	3	3	3	1	2	3	2	1	3	3	3	1	2		
Nechako River:																		
Area A _N – South Bank at Confluence	1	1	1	1	1	1	1	1	3	2	1	3	3	3	1	2	18	1
Area B _N – North Bank east of John Hart Bridge	2	2	1	2	2	2	2	2	6	4	1	6	6	6	2	4	35	6
Area C _N – North Bank near Confluence	1	1	1	1	3	2	1	1	3	2	1	3	9	6	1	2	27	3
Area D _N – North Bank west of John Hart Bridge	2	1	1	1	2	2	2	2	6	2	1	3	6	6	2	4	30	4
Area E _N – North Bank at Morning Place	2	2	1	3	3	3	3	2	6	4	1	9	9	9	3	4	45	7
Area F _N – South Bank at Foot Hills Bridge	2	1	1	3	1	3	2	10	6	2	1	9	3	9	2	20	52	9
Area G _N – South Bank between John Hart and Foothills Bridges	2	1	1	3	1	3	2	10	6	2	1	9	3	9	2	20	52	9
Fraser River:																		
Area A _F – West Bank at Yellowhead Highway	3	1	2	3	3	3	3	10	9	2	2	9	9	9	3	20	63	13
Area B _F – West Bank at South Fort George	3	1	2	1	2	2	2	2	9	2	2	3	6	6	2	4	34	5
Area C _F – West Bank at Hudson's Bay Slough W of Queensw.	3	1	2	1	1	1	1	1	9	2	2	3	3	3	1	2	25	2
Area D _F – West Bank at Lansdowne South End	3	3	2	3	1	3	3	2	9	6	2	9	3	9	3	4	45	7
Area E _F – West Bank at Island upstream of Confluence	3	3	2	3	3	3	3	10	9	6	2	9	9	9	3	20	67	14
Area F _F – West Bank at Northwood Pulpmill Road	3	1	2	2	2	2	1	10	9	2	2	6	6	6	1	20	52	9
Area G _F – West Bank across from Shelley	3	1	2	3	3	3	2	10	9	2	2	9	9	9	2	20	62	12

Notes:

1. High(1) =Flooding may occur in winter and spring. Medium(2)=Winter flooding with ice and freezing temperatures. Low(3)=Spring flooding.
2. Deep(1)=Average depth>1m. Medium(2)=Average depth approx 0.5m. Shallow(3)=<0.5m.
3. High(1)=Long duration/sudden fluctuations. Medium(2)=Medium duration/little fluctuation. Low(3)=Short duration/no fluctuation.
4. High(1)>25. Medium(2)= 5 to 25. Low(3)<5.
5. High(1)=Critical infrastructure affecting a large number of people. Medium(2)=Some people outside direct area affected. Low(3)=Only local residents are affected.
6. High(1)>\$25M. Medium(2)= \$1M to 25M. Low(3)<=\$1M.
7. Large(1)>50 ha. Medium(1)=4 to 50 ha. Small(1)<4ha.
8. Cost Effectiveness Ratio High(1)>2. Medium(2)=1 to 2. Low(3)<1.0. Ratio=10 indicates no direct protection is proposed at the moment.

8. RECOMMENDATIONS

The following recommendations are provided:

1. The City should proceed with the necessary general and area-specific projects outlined in this report.
2. An order of priority for undertaking the projects was developed based on engineering considerations but the City should review the priority setting in terms of non-engineering considerations as well.
3. The Cottonwood Island side channel enlargement was not included in the priority matrix since it does not protect against the flooding that determines the FCL's for the area. The City should review the most appropriate timing for proceeding with this project. The project has two phases, with the cost of Phase 1 (gravel removal, engineering and environmental work) at \$390,000 and Phase 2 (construction) at \$3.5 M.
4. The total cost of the general projects was estimated to be \$217,500 and it is recommended that this work be carried out over the next few years.
5. The total engineering cost of the various flood control solutions is \$545,000. It is recommended that the different projects be implemented within the next five years, starting as soon as the necessary general investigations have been completed. The total Class D cost estimate of all the proposed projects is \$39,700,000.
6. During the public consultations a number of questions of a political nature were raised that the City is encouraged to respond to. The engineering questions raised were broadly answered in this Phase 2 report.

9. REFERENCES

BC Ministry of Environment. 1981. Floodproofing New Residential Buildings in British Columbia.

BC Ministry of Environment et al. 2007. BC Flood Plan. Consequence Management Series.

Fraser Basin Council. 2004. Floodplain Mapping. Guidelines and Specifications.

Fraser Basin Council. Undated. Floodproofing in Historic Settlement Areas.

www.fraserbasin.bc.ca/publications/documents/floodproofing.pdf

M. Miles and Associates Ltd. (MMA). 2008 a. Nechako River at Prince George Flood Hazard Study: Compilation and Interpretation of Historical Air Photos. Unpublished report prepared for The City of Prince George.

M. Miles and Associates Ltd. (MMA). 2008 b. Nechako River at Prince George Flood Hazard Study: Identification of Local Sediment Sources. Unpublished report prepared for The City of Prince George.

Northwest Hydraulic Consultants et al. 2008. Flood Risk Evaluation and Flood Control Solutions Risk Analysis – Progress Report 1.

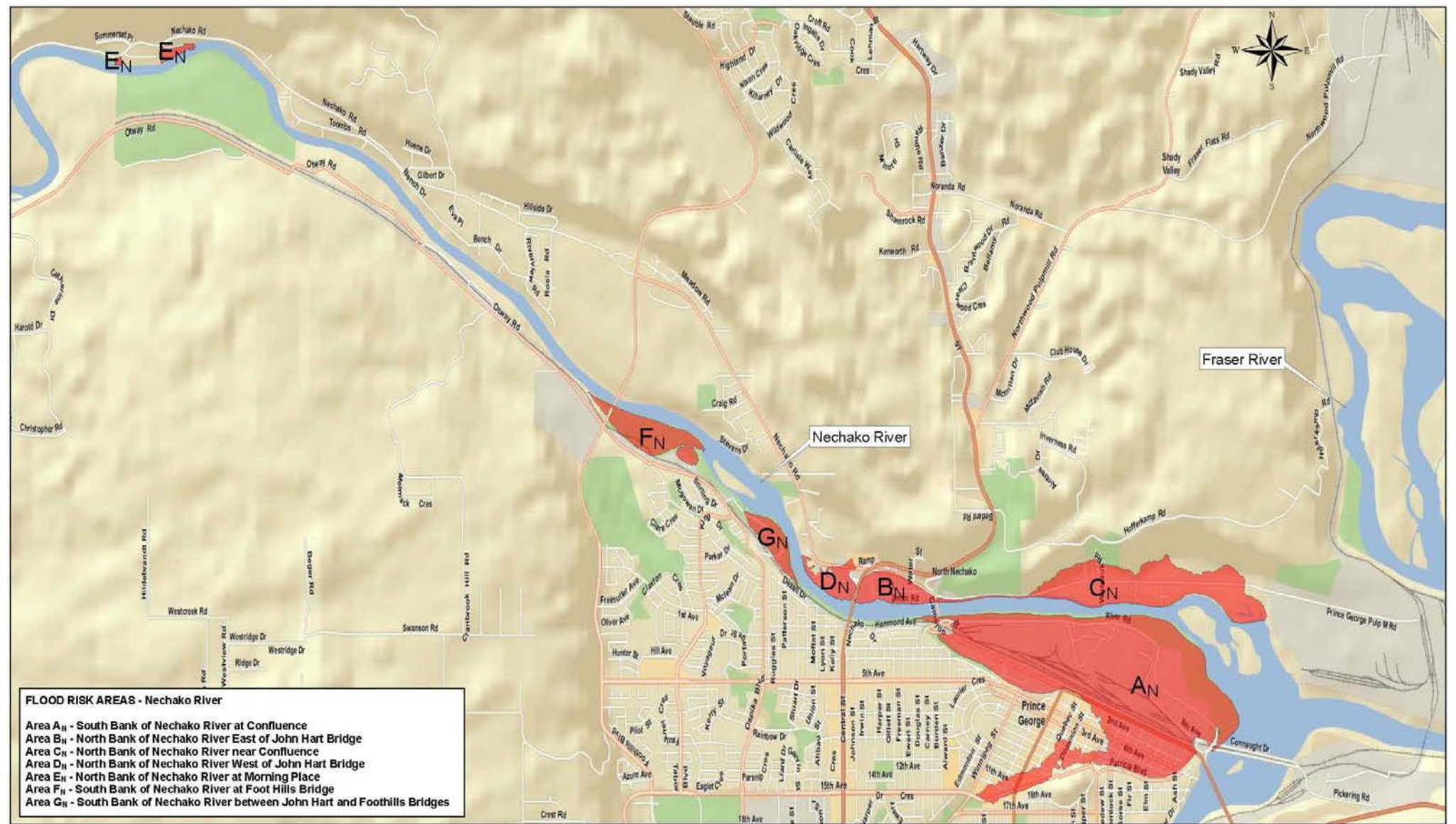
Northwest Hydraulic Consultants et al. 2009. Flood Risk Evaluation and Flood Control Solutions Risk Analysis – Phase 1 Final Report.

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City of Prince George

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MAPS



FLOOD RISK AREAS - Nechako River

Area A_N - South Bank of Nechako River at Confluence
 Area B_N - North Bank of Nechako River East of John Hart Bridge
 Area C_N - North Bank of Nechako River near Confluence
 Area D_N - North Bank of Nechako River West of John Hart Bridge
 Area E_N - North Bank of Nechako River at Morning Place
 Area F_N - South Bank of Nechako River at Foot Hills Bridge
 Area G_N - South Bank of Nechako River between John Hart and Foothills Bridges

Notes: 1- For Fraser River Flood Risk Areas see Map 2.
 2- Outline of risk areas is based on 1997 floodplain maps.

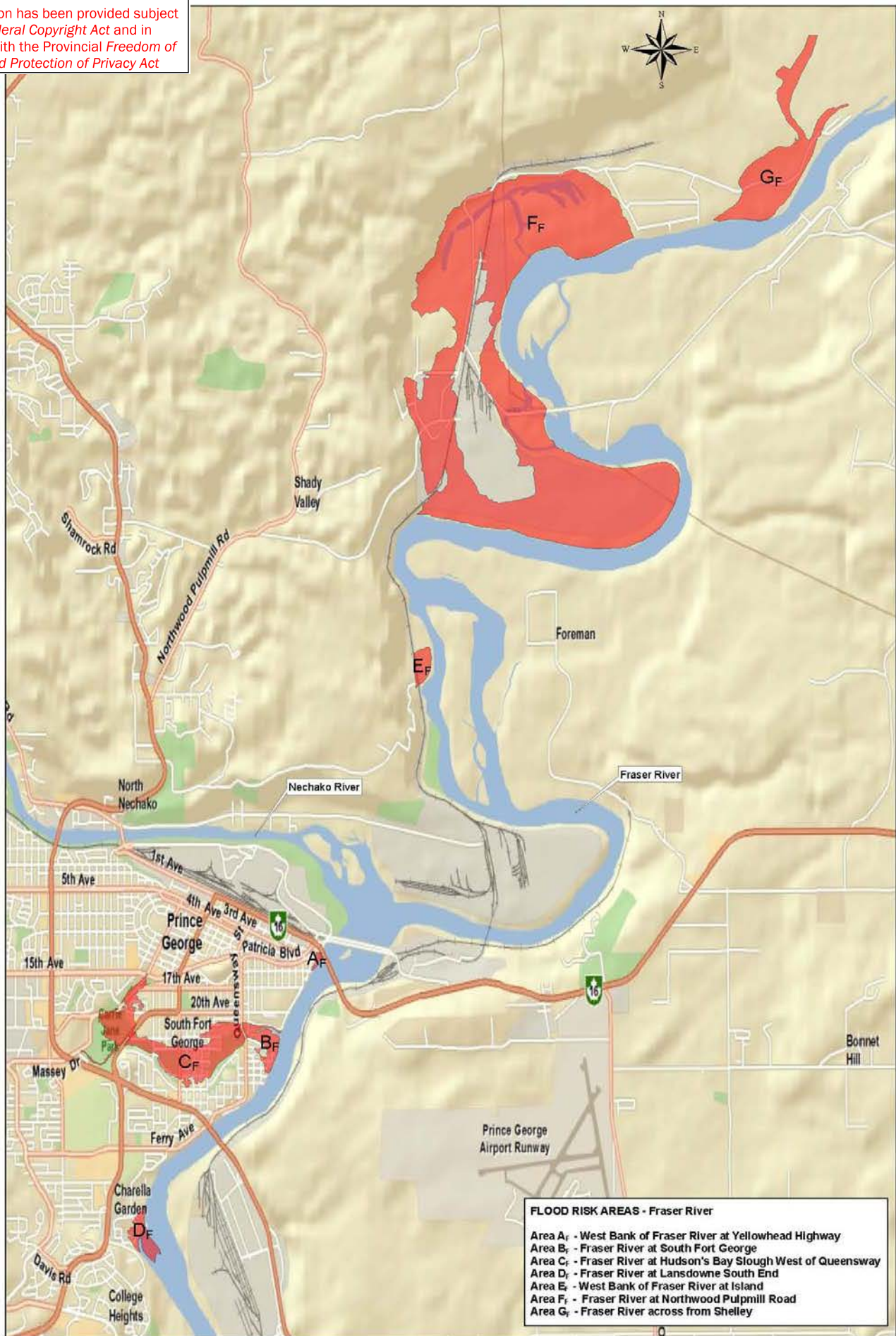
Legend

Areas at Risk (Nechako River) as identified in "Flood Risk Evaluation and Flood Control Solutions - Phase 1 Final Report"



LTM, Zone 10 (NAD 83) - Units: Meters

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FLOOD RISK AREAS - Fraser River
 Area A_F - West Bank of Fraser River at Yellowhead Highway
 Area B_F - Fraser River at South Fort George
 Area C_F - Fraser River at Hudson's Bay Slough West of Queensway
 Area D_F - Fraser River at Lansdowne South End
 Area E_F - West Bank of Fraser River at Island
 Area F_F - Fraser River at Northwood Pulpmill Road
 Area G_F - Fraser River across from Shelley

Notes: 1- For Nechako River Flood Risk Areas see Map 1.
 2- Outline of risk areas is based on 1997 floodplain maps.



Legend

Areas at Risk (Fraser River) as identified in "Flood Risk Evaluation and Flood Control Solutions - Phase 1 Final Report."

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APPENDIX A
REPORT ON COMMUNITY MEETINGS
BY FRASER BASIN COUNCIL

Flood Risk and Control Solutions

Report on the June 16 - 17, 2009 Community Meetings

Prepared by the Fraser Basin Council



*Photo: Discussion tables during June 17 sessions
Credit: Dave Dyer, City of Prince George*



Fraser Basin Council

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Flood Risk Evaluation and Flood Control Solutions June 16-17 Community Meetings at the Prince George Civic Centre

Prepared by Fraser Basin Council

1. Introduction

Following the ice jam flood event on the Nechako River in the winter of 2007/08, the City of Prince George (the City) initiated work to better understand and evaluate the flood risks posed by the Nechako and Fraser Rivers and to identify preferred management options to protect the community from those flood risks. The City retained a technical team led by Northwest Hydraulic Consultants to undertake this analysis. The City also recognized the importance of learning from residents, businesses, stakeholders and the community at large about their experiences, observations, interests and perspectives on flooding and flood management issues.

It was acknowledged that there would be significant value from facilitating a public and stakeholder engagement process as part of this project. In the spring of 2008, the City retained the Fraser Basin Council to facilitate a series of community engagement sessions to complement the technical analysis of flood risk evaluation and flood control solutions. This engagement process would complement the technical study by demonstrating to the community the commitment of the City in addressing the flood hazard management issue, ensuring that the public and stakeholder groups are informed about the project, and by providing opportunities for the public and stakeholder groups to provide input and feedback to the project based on their perspectives and experiences.

The goals of the public and stakeholder engagement process were to:

1. To inform the public and stakeholder groups of the project scope and approach.
2. To learn from the public and stakeholder groups about their perspectives and experiences in regards to flood hazard management issues in Prince George.
3. To inform the public and stakeholder groups of progress during and after phase 1 of the project.
4. To provide other opportunities to distribute information and receive feedback.

The community process was initiated in the spring of 2008 with several meetings held in May to introduce the project, to answer questions from the public and to inform the technical analysis. Follow-up meetings were held in July of 2008 to report on progress, to share preliminary findings and to solicit additional feedback from the community.

The Flood Risk Evaluation and Flood Control Solutions Report was submitted to the City and presented to City Council on May 25. The report and an Executive Summary were made available on the City's website at www.city.pg.bc.ca. This concluded Phase 1 of the technical analysis and set the stage for another round of community meetings and other

opportunities for residents, businesses and others to learn about the flood risks and recommended management options. It also offered an ideal time to answer questions from the community and to learn and report on the input, feedback, suggestions and concerns from the community. Three options were developed to solicit community input following the completion of the Phase 1 report, including:

1. Survey – a short survey feedback form in web and print formats
2. Open houses on June 16 and 17
3. Facilitated dialogue sessions on June 17.

For more information on the scope and design of these options, see the Attachments to this report.

2. Overview of the Team

Technical Team

Monica Mannerstrom, nhc (Hydrology and Hydraulics)

Dave Andres, nhc (Ice Jams)

Mike Miles, Mike Miles & Associates (River Geomorphology)

Rob Van Schubert, Environmental Dynamics Inc. (Fish and the Environment)

Bill Cheung, McElhanney Consulting Services Ltd. (Evaluation of Management Options and Cost Estimates)

Fraser Basin Council Team (Community Meetings: planning, design, moderating, facilitation, and note taking)

Laurie Vaughn, Assistant Regional Manager, Cariboo-Chilcotin Region

Jillian Merrick, Associate Regional Manager, Upper Fraser Region

Steve Litke, Senior Manager

Kim MacLean, Project Coordinator

Joan Chess, Sustainability

Facilitator, Northern Region

City of Prince George

Dave Dyer, Chief Engineer

Volunteer Support (facilitation and note taking)

Theresa Healy, UNBC

Ian Picketts, UNBC

Rhianna Everett, UNBC

Toby Turner, UNBC

Erin England, UNBC



*Photo: Technical Team during June 16 presentations
Credit: Dave Dyer, City of Prince George*

3. June 16 Presentations by Technical Team and Community Discussions

The following is an overview of the procedures and subsequent discussion of the June 16 Open House and Presentations, which were designed to present residents on the findings of the report in order to better assist them in providing informed feedback on the flood risks and proposed solutions.

a. Welcome and Introductions

Steve Litke welcomed the participants and gave an overview of the two days of community meetings and open houses. Steve explained that the purpose was to provide an opportunity for residents, property owners and the broader community to learn about the technical information including an analysis of flood risks and flood management options.

Steve introduced Dave Dyer, Chief Engineer with the City of Prince George who is the staff lead on the flood management project. Dave explained the City's interest in resolving the issue and acknowledged the importance of input from the community. Dave asked the question about how people found out about the meeting. A show of hands indicated that both letter invitations and media notices were helpful in inviting people to participate.

Steve then introduced each of the speakers, who provided a presentation on their respective parts of the project, including:

- Monica Mannerstrom - Overview
- Mike Miles - River Geomorphology
- Monica Mannerstrom - Hydrology and Hydraulics
- Dave Andres - Ice Jams
- Rob Van Schubert - Fish and the Environment
- Bill Cheung - Evaluation of Management Options and Cost Estimates

Mayor of Prince George, his Worship Dan Rogers was present and spoke to the desire of City Council to engage residents in the process and work together to provide long-term solutions for flood risk in the City. He encouraged residents to attend the June 17 meeting to discuss the options in more detail and he thanked the province for providing their support to the process.

There were questions and discussion between the individual presentations and after the panel had completed all of the presentations. These questions and points of discussion have been included in the overview of the feedback provided the following night at the June 17 World Café discussions.

4. June 17 Open House and Community Discussion Sessions

The following is an overview of the procedures and discussion that took place during the June 17 open house and World Café sessions, which were designed to facilitate community discussion of the report and the suggested management options. Residents were also invited to provide feedback through an online survey that was open for one month after the community discussion sessions. The questions in the survey were similar to those posed at the discussion tables, and the survey responses have been included in the overview of feedback below.

a. Welcome and Introductions

Steve Litke welcomed the participants and introduced Dave Andres, technical consultant with NHC. Dave gave a brief presentation, similar to that given to City Council on May 25, 2009 to help summarize the presentations that were made the previous night.

Theresa Healy from UNBC then provided some insight into the World Café process to encourage healthy and respectful discussion.

The World Café sessions were organized into two rounds. The first round consisted of small table discussions of the specific management options, and tables were given 10 minutes to discuss each one, allowing all participants to provide feedback on all of the options.

The second round of the World Café sessions consisted of small table discussions based on specific areas in Prince George that are at risk to flooding. These discussions lasted nearly one hour, with a brief interlude to allow participants to change tables if they had more than one geographic area of interest. Most participants had only one geographic area of interest.

Throughout both rounds, participants were given the option of providing insight at a general discussion table if they felt their concerns were not being met at the discussion tables that were organized for a particular area or management option.

The feedback from participants has been sorted by topic below. Comments and concerns that did not relate to a specific management option or geographic area have been listed under the general topic heading.

To minimize duplication within this report, comments that were common, or repeated often have been marked with an asterisk *

b. General Comments from June 16 and June 17 Sessions

Fairness in Decision Making

- There must be fairness in priority setting and funding*
 - o Not just based on population density
 - o Not just based on damage severity
 - o Not just based on property values
- Ombudsman needed in the process

Information to Support Public Understanding and Technical Analysis

- More information needed to be able to fully discuss the options*
 - o i.e. individual flood-proofing measures – what would this entail?
 - o More specific details needed
 - o Residents need more information, related to flood levels/risk and the proposed management options so they can become more involved with the work that needs to be done on or near their properties
 - o Residents need more information so they can make decisions now
- Where is the new 200-year floodplain level? This will not be known yet until new floodplain maps are prepared. These air photo maps [from NHC report] show the old 1997 line [ie. flood level].
- A cross section of the gravel bar at the Nechako needed for the discussion around sedimentation
- How were the different management options determined for different areas?
- The timeline is too long before solutions will be implemented
- The recommendations seem generally well-supported by the scientific and technical evidence

Monitoring and Managing Water Flows

- Water levels at Ootsa Lake need to be monitored more closely

Some participants thought that flooding on the Nechako could be attributed to the mismanagement of flow regimes at the Kenny Dam reservoir, and calls for action to make Rio Tinto Alcan more responsible were common throughout almost all discussions*

- o Alcan should be accountable for flows that it releases as they impact flood risk
- o Alcan should pay for damages and mitigation efforts

- A maximum amount of water should be released in November/prior to freeze up to avoid releasing too much at times when ice jam flooding poses a higher risk
- The City should pursue legal action

Costs

- What were the costs of the emergency measures taken in response the recent flooding?
 - Emergency measures may have been mismanaged because of the panic circumstances
- During the flood, people were promised that the province/PEP would reimburse them 80% up to \$200,000 and they weren't.
- How much is the report costing?

What did you find interesting or surprising among the report's findings?

- Surprised that the Alcan flows were 'minimal' during the 2007 freeze up
 - Many felt the report was avoiding the responsibility of Alcan and that both the government and Alcan should be held liable*
- Many were surprised that dredging will have no effect*
 - Why dredging would not work? How would lowering the channel make thicker ice? A better explanation is needed.
- Not many details were provided on the specific options related to individual flood-proofing measures
- Surprised to see that so many channels have been filled historically and are now covered by industrial land uses. It is interesting to suggest that some channels may be re-established
- Surprised that doing nothing/status quo will cost more than mitigation efforts;
- Surprised that dykes are more effective than dredging;
- The timeline for implementation of solutions is too long
- Surprised that dredging would be ineffective, but thought the report was a good assessment of the flood risks. The work done by the team seems thorough and accurate
- Temporary flood-proofing measures should not be ruled out

Feedback on Public Meeting Process

- Discussions based on areas were much more useful than discussion based on specific options

Other Recommendations

- While there are many agencies involved and the city does not hold complete jurisdiction over the river , we need to act now to get the recommendations of the

report implemented. Funding from various levels of government needs to be sought over the next five years, and discussions of cost-sharing with residents need to be had.

5. June 17, Round One: Flood Management Options

a. Re-establish Natural Back Channels

For this recommended option, what do you see as the advantages and/or disadvantages?

Advantages:

- This would bring the area back to its natural state
- The existing side channel saved town from flooding in 2008
- This would enhance recreation opportunities (camping, canoeing)
- This would contribute toward fish habitat enhancement
- This is the best option of all those suggested *
- This option can be used in conjunction with other options
- This would improve landscaped areas
- This would reduce the amount of standing water, and therefore, would result in fewer bugs
- There may be fewer regulations with this option
- This option may coincide with Railway and Forestry museums plans for expansions and land change

Disadvantages

- Mismanagement of the channel has cost money in the past
- The channel might ice up and contribute to thicker ice
- No modeling has been done for channel construction and function like some other options
- This option will not provide spawning habitat for sturgeon
- We need to plan for maintaining the channel (i.e. can heavy equipment be used when necessary? Can air lines be added?)

Participant Questions

- Will there be fair market value for any properties that need to be moved? *
- What will happen with the pulp mills?
- How will back channel move more water out of main channel?
- Why not touch the main channel?
- Where's the money to do the job?
- Where's the added water to go in the Fraser?

How should responsibilities be shared?

- There should be greater emphasis on the province for funding
- All levels of government should be responsible for maintenance after construction
- The city should be responsible for changes to the land *
- Responsibilities should be shared equally between the federal and provincial governments

b. Land Use Change

For this recommended option, what do you see as the advantages and/or disadvantages?

Advantages

- If you do it once (i.e. purchase the land), you don't have to do it again
- It's a really good option
- This option has a lot of potential to create beautiful green spaces (e.g. Toronto rail yards were converted to green space along the lake front.

Participant Questions and Comments:

- How land-use change is implemented is critical *
 - o Voluntary or expropriation?
 - o Timing?
 - o Property evaluation – how will property values be determined?
 - Current assessments and zoning? Property values may change over time
 - o Compensation or relocation?
- If someone does not want to sell, then what?
 - o Can an owner be forced to sell?
- Which particular properties are included in this proposed option? If excluded, why?
 - o Is this option based on surface or ground water seepage flooding?
 - o What degree of flooding warrants land use change?
- Would entire properties be acquired or only a part? For example, you may only need to acquire a portion of a property to allow room to build a dike
- How long would it take before an owner is notified?
 - o An owner may be left wondering about improvements or renovations (i.e. there is uncertainty for many landowners).
- Will decisions be made fairly, from one area to another, by a number of people in one area versus another, and between residential and business owners?
- How will the City set priorities?
- Where will the funding come from? *
- Fair market value should be used (i.e. do not consider the property to be devalued by flood risk.
 - o Would you use replacement value or appraised value?

How should the responsibilities be shared?

- The City holds responsibility for allowing development
- The City must enforce the new 200-year floodplain (predicted extent and depth of flooding)
- How was Island Cache handled in terms of responsibility and process?
- The Provincial and Federal governments must uphold their responsibilities for the rivers

c. Building Dikes

For this recommended option, what do you see as the advantages and/or disadvantages?

Advantages

- One dyke will protect a large area
- Dikes are a preferred option where surface water flooding is the biggest issue

Disadvantages

- There is worry over the loss of land by property owners
- There will be a need to build dykes around the pump houses on the Nechako and Fraser
 - o pumps across from Preston ran full time to keep the water down
- Dikes may exacerbate the problem by holding in water that should be released
- If the floodwaters rise and fall quickly, dikes may be effective; however, if the water rises and falls slowly it will seep into the ground and may still cause flooding
- May not be the solution for flooding from water below ground level *
- Dikes are not visually pleasing
- Property owners do not want trails/people/dogs walking by their properties
- Many Nechako and South Fort George residents feel dikes would not be effective
 - o Related to this issue of surface water vs. ground water
- Dikes may cause erosion problems on the opposite banks
- Setback dikes may result in isolation of properties and divide neighbourhoods *

Other Comments

- The river is too wide. There is a need for better velocity

There was disagreement among some participants about the need for dikes in certain areas (e.g. Lansdowne)

- Dikes should be finished with trails
- Dikes need to be accompanied by pumping stations and seepage barriers
- How will the size and placement of the dikes be determined?

How should responsibilities be shared?

- The federal government allowed the development and governs them, so they should share the responsibility
- The three levels of government are responsible, along with industry
- There is too much control at the top
- There is frustration that the City will bend over backwards to save 7 fish (with a cost of \$32 million), yet they are not willing to protect people and land
- The City should not accept having no influence on making Alcan accountable. The City is here to protect our interests and they do have a say with the other levels of government *

d. Raising Roads

For this recommended option, what do you see as the advantages and/or disadvantages?

Advantages

- Raised roads would provide access to flooded areas during emergency
- There are many brownfield/contaminated sites in the floodplain
 - o Blockage of flood waters from these areas would have an environmental benefit with reduced water contamination

Disadvantages

- Raising roads may be ineffective in preventing damage from ground water *
- There are concerns that properties on the riverside of raised roads may be adversely affected
- There are concerns that raised roads may affect water levels, and increase ground water pressure, flows, etc
- Raised roads may create drainage issues – one resident suggests that this has become a problem with his property on PG Pulpmill Road *
- This option may be very costly in order to make it effective (i.e. subsurface barriers, culverts, complexity in raising River Road)
- Fairness is a concern (i.e. raising roads would negatively affect some properties while protecting others
 - o Particularly in regard to subsurface flooding
- There are concerns about isolation (i.e. neighbourhoods would be divided up)*

Other Comments

- Raised roads would have to be properly designed to function effectively (i.e. perform as a dike)
 - o This would come with a high financial cost

e. Flood-proofing Individual Buildings

For this recommended option, what do you see as the advantages and/or disadvantages?

Disadvantages

- Works may not be very attractive
- Changing elevation of industrial buildings can cause major problems in production lines

Other Comments and Questions

- Are there landscaping options that would help (.ie ditching and swails)
- Ditching may not work under freeze-up conditions
- How can we protect septic and utility systems?
- A lot of flood water comes from seepage up through the ground (Delhaven, South Fort George). Barriers to prevent this are needed *
- Who would determine the kind of work that would be done of each property (landowners, city, engineers?) *
- New flood-proofing has to connect smoothly with existing structures/landscapes
- What kind of work/structures does this entail?
- A safe elevation needs to be determined – information is key
- Property owners need the right information to make decisions on how to take individual flood-proofing measures *
- Many suggested that they have accepted the loss of the use the of their basements, but this is not a long-term option (mold, structural problems over time)
- This may be a better option for new homes, not existing ones
- Pump stations would still be needed
- Will houses have to be raised to 200-year level or a more common level of flooding?
- More flood-related information on specific properties needs to be available to prospective buyers
- In many cases the information is wrong or outdated (e.g. Morning Place is not located in the current map of the floodplain, and new owners were told there had been no history of flooding)
- Taxes for affected property owners should be reduced
- Who is going to pay for individual flood-proofing?
- Will these measures be forced or voluntary?
- Individual flood-proofing measures are more desirable for those who do not wish to move

How should the responsibilities be shared?

- Alcan must take responsibility for flow regimes and cover damage costs
- The City should not have issued building permits in flood zones. The City is responsible for land use decisions
- Federal and provincial governments should provide grants to homeowners for individual flood-proofing efforts
- There may be some opportunities for cost-sharing between residents and levels of government

6. June 17, Round Two: Areas at Risk to Flooding

a. Area Af to Df – Fraser River from Yellowhead Bridge to Lansdowne Road

How would the proposed options for this area affect you?

South Fort George - Farrell Street:

- There is no room for diking; it would need the entire property *
- The area is all older homes, which all pose a different set of problems for flood proofing (i.e. raising houses)
- Farrell Street gets flooded by Fraser high water
- What is the timeline for implementing the options?
- If property owners have to raise their homes, they will need financial help
- If the federal government can bail out GM, it can bail out South Fort George and Lansdowne

South Fort George – Regent Street:

- A dike would spoil the view and could be ineffective because it is a groundwater flooding problem*
- This area has groundwater seepage. Only two of the six homes get water in their basements
- Could raise those homes by 2 feet plus a sump pump, which would solve the problem

Wiens Road:

- Flooding is not a problem at the end of Wiens Road
- Strong opposition was expressed for a dike at the end of Wiens Road

Lansdowne

- There is opposition to diking
- There is a preference for raising a house (i.e. flood proofing)
- Just one home is really affected and the owner supports raising their home (the last house on Lansdowne)

Other options?

For both neighbourhoods, no other options were suggested

Comments and/or suggestions for City Council

- Raise the homes for the few homes affected by groundwater seepage
- Move on in a timely manner (i.e. take the study and implement it)
- Let residents know what's happening. Keep us informed *
- Engage Rio Tinto Alcan

b. Area Ff and Fg - Landooz Road, Northwood Pulp, north bank across river from Shelley

- No participants attended this discussion table

c. Area An – South Bank of Nechako River including River Road Industrial Area and Downtown Prince George

Questions and Comments

- Why not consider land use change through all of An? It would not be fair or consistent to impose re-zoning on some properties but not others *
- Why protect some by raising River Road and building a setback dike while isolating others on the river side of the dike, with impacted access and potentially devalued properties?*
- There was a general concern that some large industrial sites would be re-zoned without further consultation
- It was acknowledged that some properties would be directly impacted by the location and alignment of a setback dike
- There was some discussion about land use change and fair value for property. It was agreed that either land trade or land purchase could work. It was noted that in 1972 there was a 3 to 1 ratio used in trading lands to property owners that moved from Island Cache
- It was suggested that if no structural works were implemented to improve flood protection for vulnerable properties, then there should be an option to buy-out anyone in the floodplain
- A specific suggestion was made to design a setback dike alignment in a way to protect and enhance opportunities for the railway museum to be expanded
- local businesses should be given an opportunity to participate (i.e. work) on any developments in their areas (related to flood protection measures)
- Residents were concerned they would not receive a fair value for their property [land use change] due to rezoning
- What kind of compensation would there be for landowners affected by dike or back channel construction?
- management options will help some but may increase flood risk/flood severity for others
- Would like to see options for individual proofing measures in this area
- The top priority should be to properly understand the risks of flooding and to prepare an action plan over the short term, and build mitigation options over the long term.

d. Area Bn - North bank east of John Hart Bridge: Ongman Road / McAloney Road light industrial area

- No participants attended this discussion table

e. Area Cn – North bank along Pulp Mill Road

Comments on land-use change:

- How will we be compensated for our property?
- How long before decisions are made so we can start planning?
- How will the value of properties be determined?
- Will our input be considered in what's going to happen?
- Properties on the north side of Pulp Mill Road are too valuable for land-use change. This option would not be well-received

Comments on flood –proofing:

- Groundwater percolates to the north side of Pulp Mill Road so how can the road be classified as a dike (as on the air photo provided)?
- Culverts are contributing to the flooding and they need to be blocked
- Flood proofing would need to include raising septic fields, out buildings and road access but who is paying for all of the work?

Other Options:

- Set back diking should be considered
- Try gravel extraction at the mouth of the Nechako
- Ditches and catchment basins should be placed in right-of-ways and between houses. This would make temporary flood response efforts easier and more effective
- The culverts under Pulp Mill Road made managing water on the north side very difficult. These culverts should be closed during flooding

Other Comments:

- Engineers should switch places with flooded out residents to experience first hand what it is like emotionally to live in a flooded area and they may change their determination

Comments and/or suggestions for City Council

- What has the cost been to date for 18 months of work both for the technical committee and the public consultation?
- Why is it taking so long to get to this stage? We are missing a window of opportunity for action
- There has been inadequate and unfair financial compensation from the disaster relief fund
- None of the studies have addressed the groundwater issue on the north side of Pulp Mill Road. This issue has been raised repeatedly but has still not received adequate attention.
- How does PG Pulpmill Road meet the standard dike requirement?
- We feel like we are not truly involved in the long term flood planning for the city
- How do you offer solutions and help for the emotional toll and uncertainty from the flood impacts?
- Diking would be ineffective if culverts are not addressed (culverts contributed to water flooding in the area previously)

- Residents feel that the meeting was simply a way to pacify them - that decisions had already been made by the city
- Many are frustrated with the promises of a quick timeline made earlier – many have no idea what to do with their properties (i.e. fix damages, etc) until they know the future plans from the city
- Many are living in damaged houses. Property values have depreciated but they are still paying property taxes based on previous assessed values
- “The City paid me \$5,900 to raise my house and it cost me \$8,000 with the total costs being \$30,000 to fix and/or replace (Wolczuk Road).” *[Note of clarification: The City of Prince George did not pay for house repairs damaged by flooding. Funding for flood repairs was funded and administered directly by the Province]*

f. Area Dn – North bank of Nechako, west of John Hart Bridge

Participant Comments

- Raising Preston Road will not do any good
 - The road has never been flooded
 - This option will cause more problems rather than fix them
 - Groundwater seepage is the problem in this area and not surface water
- Diking systems (and raised roads) need to have underground barriers and pumping systems to deal with groundwater and drainage issues

The group is strongly in favour of dredging. This led to lengthy question and answer period with Mike Miles and Dave Andres around sedimentation and ice-related flooding

Group Discussion with Technical Experts

Mike Miles premised the discussion by restating that flooding on the Nechako and Fraser Rivers is a natural occurrence, and will continue to occur regardless of changes to channel morphology

Mike explained in detail the sedimentation at the mouth of the Nechako over time and its effect on flood levels

Dave Andres provided a detailed explanation of ice jam formation and its effect on water levels

Participants at the table agreed that the explanation was useful, but that information was still unclear

It was suggested that more time be devoted to a detailed overview of the sedimentation and ice formation at the mouth of the Nechako so that residents could fully understand the conclusion that the technical team had reached.

g. Area En - Morning Place

Participant Comments

- The options described for this area are general. There should be a management and mitigation option developed specifically for this area.
- The options seem a little too abstract.

Residents would have liked more specific details as to which houses the City of Prince George had earmarked for land use change

- Have a covenant on the land.
- Residents agree to have temporary gabion dykes when necessary during a flood event if the city provides the machinery and supplies. A land owner agrees to provide labour and cleaning of site following removal of dykes.
- Residents do not agree to the assessed land value, due to the value being based on figures from BC Assessment data, and not the current real market value.
- Following previous flooding and removal of dikes, there was a promise to fix the areas that had been altered to facilitate dyke placement. The residents felt that the repair was inadequate.
 - o Hydroseeding of lawns is both an aesthetically and financially inefficient method of land repair.
 - o Concerns regarding the general garbage the contractors had left after finishing the job.
 - o Some properties have not been fixed in an orderly manner.
- If the properties were bought out by the City of Prince George, the loss to the residents would be far greater than simply financial *
 - o The property cannot be recreated almost anywhere else in the province, regarding river front property.
 - o The residents bought property for the location and views, and are understanding of the inherent risks assumed when purchasing waterfront property.



*Photo: Discussion tables during June 17 sessions
Credit: Dave Dyer, City of Prince George*

7. Conclusions

Overall, the community open houses and meetings were well attended and the goals of these sessions were achieved. The presentations by the technical team were very informative and well received by the participants. Participants had opportunities to have their questions and concerns addressed and recorded and also had opportunities to put their suggestions and preferences forward for consideration by City Council and/or the technical team. The following is a summary of some of the highlights, recurring themes and recommendations for consideration.

a. Information to Support Public Understanding and Technical Analysis

- More information is needed to help the community better understand and fully discuss the management options*
- Some of the management options and risk areas were not assessed to the same degree as others.
- The updated 200-year floodplain level is a critical next step to help inform residents, businesses, and other decision makers about the design and implementation of flood management options.

b. Flooding from Groundwater Seepage

- Many risk areas are vulnerable to flooding from the seepage of groundwater and rising water tables during river flooding*
- This circumstance needs to be fully considered in the selection, design and implementation of flood management options such as floodproofing, flood protection dikes, and raised roads (if raised roads are expected to perform like a flood protection dike).

c. Monitoring and Managing Water Flows

- Some participants thought that flooding on the Nechako could be attributed to the mismanagement of flow regimes at the Kenny Dam reservoir, and calls for action to make Rio Tinto Alcan more responsible were common*
- There were questions about accountability and possible liability for flood damages associated with Rio Tinto Alcan.
- More information is needed about how the operation of dams and spillways as well as natural flows from unregulated lakes may or may not contribute to flood flows on the Nechako River.
- Increased contact, communication and information sharing between Rio Tinto Alcan and the City of Prince George is suggested.

d. Recommended Management Options

- There was substantial feedback on each of the recommended management options; however, there was no clear consensus among all participants. For each of the management options, a number of advantages and disadvantages were identified, and there remain many questions within the community. Many of these comments and questions are site specific and warrant further consideration along with technical

considerations during the selection, design and implementation of flood management options.

e. Sedimentation and Dredging

- Many participants were surprised that dredging will have little or no effect on reducing flood risk and some disagreed with this analysis*

f. Collaboration and Cost-Sharing for Implementation

- There were concerns that the timeline is too long before solutions will be implemented*
- There are many agencies involved and the city does not hold complete jurisdiction over the river; therefore, there is a need for collaboration among all relevant jurisdictions to result in timely implementation.
- The City has limited financial resources; therefore, funding from various levels of government needs to be sought over the next five years, and discussions on cost sharing with residents need to be had.

g. Fairness in Decision Making

- There must be fairness in priority setting and funding*
- It was suggested that there is a role for an Ombudsman to help facilitate a “fair” process

The community process described in this report has served multiple benefits. It has provided an opportunity for community members to learn about the findings from the technical analysis both in terms of flood risks and recommended management options. It has also provided an opportunity for City Council and staff to learn about the interests, knowledge, perspectives and preferences of community members, for consideration alongside the technical facts, figures and analysis.

Optimal solutions that will provide long-lasting flood protection benefits to the community at large are most likely to be found through listening and learning from a broad diversity of perspectives and insights. In particular, local knowledge can also help build a depth of understanding about site-specific conditions to help tailor creative solutions for particular areas. The community process and this report are intended to share these types of community perspectives with the City of Prince George to support thoughtful deliberations and decisions to manage the flood risks faced by the community now and in the future.



*Photo: Participants during June 16 presentations
Credit: Dave Dyer, City of Prince George*

Attachment 1: Briefing Note

Flood Risk Evaluation and Flood Control Solutions Study Briefing Note – Community Engagement Process of the Fraser Basin Council

The Fraser Basin Council has been retained by the City of Prince George to facilitate a series of community engagement sessions in parallel with the technical analysis of flood risk evaluation and flood control solutions. The next phase of community engagement is to obtain public input and preferences on the recommended options for consideration by City Council along with technical, financial and other factors. Three options are available to solicit community input, including:

1. Survey – a short survey feedback form in web and print formats
2. Open houses on June 16 and 17
3. Facilitated dialogue sessions on June 17.

The community will be notified about these sessions through the May 25 media briefing and Council meeting as well as media releases, newspaper advertisements and invitations mailed to residents and business affected by recent flooding.

1. Survey – Web-based and Print Formats (June 16 – July 13)

The City of Prince George website will enable the community to download the technical report and/or the Executive Summary and will include a link to a web-based survey for people to submit their input. A print version of the survey could also be downloaded from the City's website and could also be picked up at City Hall or requested by phone, fax, mail and email. Completed surveys would be returned to the Fraser Basin Council for collation of the results. The survey questions would be the same as those used in the facilitated dialogue sessions (see below).

2. Open Houses – Civic Centre (5:30 pm – 7:00 pm on June 16 and 17)

Open houses will include display material, copies of the Executive Summary, copies of the survey feedback form, and members of the consulting team available to explain the information and to answer questions. **After the June 16 Open House, members of the technical team will present information on particular aspects of the flood risks and flood management solutions.**

3. Facilitated Dialogue Sessions – Civic Centre (7:00 – 9:30 pm on June 17)

Dialogue sessions, using the World Café Process (www.theworldcafe.com), will be facilitated for participants to learn about and discuss the different flood management options and the different areas that are vulnerable to flooding. A summary presentation will be provided immediately prior to the dialogue sessions in the evening on June 17, and resource people will be available to help answer questions and clarify issues to support informed participation. The World Café process is based on small groups (8-10 people)

supported by facilitators, to encourage thoughtful and informed dialogue by focusing the discussion around several questions. The following are the proposed questions to solicit community feedback:

1. What do you find the most interesting or surprising among the findings in the report?
2. Of the recommended options, which do you prefer [overall or for specific areas]?
3. How would these options affect you either positively or negatively?
4. What options suggested make the most sense for which areas?
5. How should the responsibilities for reducing the vulnerability to flooding be shared?
6. What other constructive suggestions do you have to help City Council make the best decisions to manage flood risks in Prince George over the long term?

FBC staff will compile all feedback received from all three options for community input and will prepare a report for consideration by City Council.

Attachment 2: Public Involvement Sessions Schedule

City of Prince George Flood Risks and Management Options Report

TUESDAY JUNE 16, 2009 – CIVIC CENTRE

5:30-7:00 pm – Open House – Room 101

Purpose: to provide an opportunity for residents and property owners to become familiar with the information and analysis; and to see the options proposed especially for their property and area.

7:00 – 9:00 pm – Technical Presentations

Purpose: to provide an opportunity for residents and property owners to learn about the technical information, analysis, and options.

Dave Dyer - Welcome

Steve Litke - Introduce Panel Speakers

Monica Mannerstrom - Overview

Mike Miles - River Geomorphology

Monica Mannerstrom - Hydrology and Hydraulics

Dave Andres - Ice Jams

Rob Van Schubert - Fish & Environmental Aspects

Bill Cheung - Evaluation of Management Options & Cost Estimates

Steve - Moderate Discussion (including questions and answers)

Steve – Wrap-up

WEDNESDAY JUNE 17, 2009 – CIVIC CENTRE

5:30-7:00 pm – Open House – Room 101 (see above)

7:00 – 9:30 pm – Overview Presentation and Small Group Discussions

Purpose: To gain feedback and to provide property owners and the public the opportunity to share their perspectives on the proposed options.

Round One

All groups to discuss each flood management option

- Build dikes (Laurie Vaughn)
- Change land use (Joan Chess)
- Re-establish natural side/back-channels (Kim MacLean)
- Flood-proof individual buildings (Jillian Merrick)
- Raise roads (Steve Litke)

Round One Questions

1. What do you find (the most) interesting or surprising among the report's findings?

2. Of the recommended options, which do you prefer?
3. How should the responsibilities be shared for reducing the vulnerability to floods?

Round Two

Each individual to select an area of interest to discuss:

- Nechako - Dn and En - north bank west of John Hart Bridge - Preston Road, Del Haven, and Morning Place (Jillian Merrick)
- Nechako - Bn - north bank east of John Hart Bridge – Ongman Road / McAloney Road light industrial area (Toby Turner)
- Nechako - Cn - north bank - along Pulp Mill Road (Kim MacLean)
- Nechako - An - south bank - River Road industrial area and downtown (Steve Litke)
- Fraser - Ff and Gf – Landooz Road, Northwood Pulp, north bank across river from Shelley (Laurie Vaughn)
- Fraser - Af, Bf, Cf and Df - west bank - NW end of Yellowhead Bridge, South Ft George, Hudson Bay Slough, and Lansdowne Road (Joan Chess)

Round Two Questions

1. How would the recommended management option(s) affect you in your area of interest?
2. Are there options that should be considered for your area, that are proposed for other locations?
3. What final comments and/or suggestions do you have for City Council to help it set priorities and make decisions about flood management in our community?

Attachment 3: Speaker Bios – June 16 – Prince George

nhc was founded in 1972 and is an international firm with offices in western Canada and the western States. The company has a worldwide reputation as water resource specialists and is the lead of the consulting team for Prince George.

Monica Mannerstrom is an associate of NHC and has been with the company the past 25 years. She has a Master's degree in water resources and a broad background in hydrology and hydraulics, with specialization in river engineering and flood management. She has performed a variety of flood risk assessments across BC including for the Lower Fraser Valley. As the principal investigator of the NHC team, Monica carried out hydrologic and hydraulic analyses and compiled the Phase 1 report.

Mike Miles is a professional geoscientist specializing in fluvial geomorphology or the study of river processes. Mike has over 30 years experience in BC. Previous work on Nechako River includes studies on the original Kemano Completion project undertaken in 1982, more recent analysis of post regulation changes in river characteristics downstream of Skins Lake spillway and a variety of investigations related to the proposed water release facility at Kenney Dam. In this context Mike has had the opportunity to inspect all of Nechako River during both low and high flow conditions. Work in the vicinity of Prince George includes erosion studies for BC Rail on Fraser River, evaluation of habitat enhancement opportunities in the vicinity of Cottonwood Island for the Ministry of Transportation and channel stability studies on Naver Creek near Hixon for the Regional District. Mike's role in the present study was to determine how Nechako and Fraser Rivers have changed over time and to investigate rates of sediment deposition or transport. He has prepared two background reports on these topics and has contributed to the final project document. His talk today will summarize these results and set the context for the hydraulic and ice jam investigations undertaken by Northwest Hydraulic Consultants Ltd.

David Andres is a hydraulic engineer and ice specialist with over 35 years of experience dealing with rivers, ice, and flooding in western Canada. He has extensive experience in monitoring and modeling river ice processes, having worked on most major rivers with ice-related problems in Alberta and northern British Columbia. His experience on the Nechako River goes back to 1997 when he advised Rio Tinto-Alcan on the freeze-up ice jamming at Vanderhoof and Prince George. Since that time he has advised Rio Tinto-Alcan on appropriate flow releases during breakup to minimize effect on the ice stability, has lead the team that updated the floodplain study at Vanderhoof, and undertook an advisory role to the City of Prince George during the 2007 freeze-up flooding event. With respect to this project, David carried out the ice analysis, determined the ice-related flood risks, and helped in evaluating the effectiveness of mitigation measures.

Rob Van Schubert is a biologist and managing partner with Environmental Dynamics Incorporated. Rob has lived in Prince George for 17 years. Rob's role in this project was to

assess the environmental components including an analysis of the fish and fish habitat values within the area of study and to provide information on the environmental risks associated with the different flood management options.

Bill Cheung is the Branch Manager, McElhanney Consulting Services Ltd., in Prince George. Bill has 20 years experience in municipal and civil engineering including forestry road and water resource management projects and various municipal infrastructure designs in central/northern BC. His recent projects include project management for commercial developments, flood mitigation, hydrology and hydraulics for bridge and culvert crossings, and site grading and drainage improvements. Bill was responsible for leading the cost analysis team, which included Jim Sosiak, PEng from McElhanney Consulting Services. Bill was involved with both the response and recovery phases during the Nechako Ice Jam Flood as technical support for the City of Prince George.

City of Prince George

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APPENDIX B

FLOODPROOFING MEASURES BY FEMA

CHAPTER 1 - INTRODUCTION TO FLOOD PROOFING

Flood proofing can be defined as “any combination of structural or nonstructural changes or adjustments incorporated in the design, construction, or alteration of individual structures or properties that will reduce flood damages.” Simply stated, flood proofing includes any effort property owners may take to reduce flood damage to individual structures and their contents.

FLOOD PROOFING OBJECTIVES

FLOOD DAMAGE REDUCTION. The potential for flood damage is determined by the depth and velocity of flooding and the number of times a structure and its contents may be flooded. Flood proofing a structure will decrease the potential for damage from future floods. Without flood proofing, a structure is subject to damage from all floods that enter the basement or rise above the first-floor level.

Flood proofing can benefit the property owner in several ways. It will save money that would otherwise be spent to repair and clean up the structure and its contents after a flood. In some cases, much or all of the contents, as well as the structure itself, are destroyed. Also, flood proofing will reduce the inconvenience and annoyance caused by the time-consuming process of cleaning up and repairing a structure. Other benefits of flood proofing may include less time off work due to flooding, improved health and safety, peace of mind knowing the frequency of flooding is reduced, and other intangible benefits.

EFFECTIVENESS. All flood proofing measures can be effective in reducing damages from floods for which the measure was designed. However, the only way to ensure complete safety from flood damage is relocating the structure to a site outside of the flood plain. When structures are not removed from the flood plain, floodwaters may rise to an elevation that overcomes any flood proofing measures-- possibly causing damages equal to or perhaps even greater than what would have been caused without flood proofing, unless the flood proofing measure used is elevation. Unless a structure is relocated out of the flood plain, the structure will still be exposed to some potential flood damage even if flood proofed.

SAFETY. Even after flood proofing, a structure in a flood-prone location will still be subject to flooding if floodwaters exceed the design level or cause failure of the flood proofing measures. Property owners must keep this in mind to avoid a false sense of security. No one should remain in a flood proofed structure during a flood, as the flooding could be hazardous and life threatening. High-velocity flows, waves, or other conditions can cause floodwaters to suddenly cause the flood proofing measure to fail, leaving occupants little or no time or ability to vacate the structure and flooded areas. In addition, rising floodwaters may inundate all overland means of escape.

FLOOD PROOFING MEASURES

Flood proofing measures either reduce the number of times the structure is flooded or limit the potential damage to the structure and its contents when it is flooded. There are four general approaches to flood proofing:

- Elevating the structure
- Relocating the structure
- Constructing barriers such as floodwalls or levees to stop floodwaters from damaging the structure
- Modifying the structure through flood proofing and relocating contents to minimize flood damage.

ELEVATION. Elevation involves raising such structures as buildings in place so that the lowest floor is above the flood level for which flood proofing protection is designed. The building is raised and set on a new or extended foundation.

Almost any structurally sound building can be elevated. Typically, the least expensive and easiest structure to elevate is a one-story frame building built over a crawl space that is at least 18 inches in height. The process becomes more difficult and expensive as different structures are considered, such as a building with a basement, a slab-on-grade building, a building constructed of brick or block, a multi-story building, or a building with additions.

Property owners wishing to use this method should employ a contractor to ensure that the building is properly raised and a safe foundation is constructed. The elevated foundation must be able to withstand erosion caused by floodwaters, the impact caused by ice and debris in floodwaters, hydrostatic and hydrodynamic force, and impact from high wind velocity and earthquake events. It is also advisable to have the building inspected by a structural engineer prior to elevation to assess the structure's ability to undergo elevation.

Buildings can be elevated on basically two different types of foundations--an open foundation and a closed foundation. Elevating a building on an open foundation involves raising it onto piers, posts (columns), or piles. If the building is located in an area of coastal flooding, an open foundation is the only way to safely elevate. If the building is subject to high-velocity riverine floodwaters, significant water depths, or potential erosion, the property owner should also consider having the building elevated on an open foundation. Doing so will allow the waters to flow beneath the building and reduce potential damaging impacts. Selection of the proper open foundation (piers, posts, or piles) for various flooding and site characteristics is critical to success. Elevating a building on a closed foundation involves raising it on extended foundation walls or on fill. Elevating on extended foundation walls is very effective where floodwater velocities are low and erosion potential is also low. Elevating on fill is very effective in almost any situation.

Elevation on Extended Foundation Walls. Elevation on extended foundation walls is normally used in areas of low to moderate water depth and velocity. After the building is raised, existing foundation walls can be extended vertically using materials such as masonry block or poured concrete. The building is then set down on the extended walls. While elevating a building on extended foundation walls is often the easiest solution to the problem of flooding, there are several important considerations. The most important concern is that the original foundation and footings must be able to withstand the extra loading, not only from the additional vertical dead load of the new wall but also from the additional flood forces from floodwater against the foundation and from wind forces against the elevated building. If the footings are not deep and wide enough, they may be unable to resist the additional loads, which could result in overturning or undermining of the walls and subsequent collapse. In addition, the original foundation walls may not be wide enough to be extended. A structural or foundation engineer should be consulted to make these determinations.

Depending on the potential flood forces, it will be necessary to reinforce both the footings and the walls using steel reinforcing bars. An equally important concern regarding new foundation wall construction is how it is connected to the existing superstructure of the building. Regardless of what type of extended foundation wall construction is used, hydrostatic and hydrodynamic forces can result in collapse of the structure support system. To eliminate the risk of damage due to hydrostatic force, extended foundation walls need to be constructed with openings or vents to allow floodwaters to enter the enclosed area and equalize the hydrostatic force.

A potential solution to the problem of excessive hydrodynamic force on extended foundation walls is to elevate the building on only two walls, spanning the building between them and leaving the two ends open. By orienting the walls parallel to the flow of water, the amount of wall area resisting the forces from floodwater velocity is less, and loading is significantly reduced. In many cases, the ends are not left totally open. For esthetic or security reasons, it may be desirable to enclose the area. This can be accomplished by installing lattice work or lightweight walls that are designed to break off during floods.

Elevation on Piers. An open foundation support structure is the pier. The piers normally used in flood proofing applications differ from those used in bridge support applications in that a pier for flood proofing consists basically of an upright support member tied to and supported by a reinforced concrete spread footing. This design allows the individual pier to resist lateral movement without the need for cross bracing between the posts as is sometimes needed in a pure post or column design. While they may be the most commonly used type of open foundation for elevating existing structures, they are the least suited for withstanding lateral flood and wind forces. In conventional use, piers are designed primarily for vertical loading. When exposed to flooding, however, they will also experience hydrodynamic forces. Piers used in flood proofing to support an elevated building must be substantial enough to support the structure and also sufficiently reinforced to resist a range of flood and wind forces.

Piers supported by reinforced concrete footings are generally used in shallow-depth flooding conditions with low-velocity flow where scour is not a problem. Piers are normally constructed of either masonry block or poured-in-place concrete. They must have steel reinforcing both in the pier itself and in the footings providing support; the steel reinforcing must be tied together to prevent separation. There must also be a suitable connection between the superstructure and the piers to resist wind and buoyancy forces.

Elevation on Posts or Columns. When flooding is characterized by moderate depths and velocities, elevation of structures on posts (also referred to as columns) is a frequently used flood proofing method. Posts are made of wood, steel, masonry, or precast reinforced concrete. Their ends are set into pre-dug holes, and material such as earth, gravel, crushed stone, or concrete is backfilled around them. Since substantial loading is usually expected, posts are normally anchored into a concrete pad at the bottom of the hole. Care must be taken to ensure that the posts or columns are embedded deeper than any expected scour depth.

While piers are designed to act as individual support units, posts normally must be braced for an additional factor of safety. A variety of bracing techniques, using several different materials, exists. The type to be specifically employed on an elevated structure in a particular area depends on local flood conditions and loads. Some of the more commonly used bracing techniques include wood knee and cross bracing, steel rods, and guy wires.

Elevation on Piles. Where high-velocity flooding can result in scouring, piles provide the best type of foundation. Piles differ from posts in that piles generally are mechanically driven into the ground usually to depths greater than that for posts. Because of this, piles are less susceptible to the effects of high-velocity floodwaters and scouring. Piles must either rest on a support layer, such as bedrock, or be driven deep enough so there is enough friction between the pile and the surrounding soil to carry the load. Piles are generally made of wood, steel, or reinforced precast concrete. They may require bracing similar to the methods described for posts. Because driving piles generally requires bulky machinery, an existing structure that is being flood proofed will have to be temporarily moved aside and set on cribbing until the driving of piles is complete.

Elevation on Fill. This measure is widely adaptable to be successful in almost any situation. The greatest concerns with this measure are erosion of the earthen fill material and settlement of the earthen fill material. The erosion potential can normally be corrected by erosion protection such as riprap. Settlement of the earthen material can be a problem if the structure foundation rests directly on the fill material such as with a slab-on-grade. If this type of foundation is used, an existing structure must be moved to the side temporarily so the fill material can be properly compacted. The best use of this measure is to elevate the structure on extended foundation walls and then place earthen fill material directly against the extended foundation walls. This reduces problems that a stand alone extended foundation wall has such a hydrostatic force, hydrodynamic force, and ice and debris flows.

RELOCATION. Relocating a structure is the most dependable way to flood proof. This method involves moving the structure to another location away from flood hazards. It is the ultimate option for the property owner who wants to be free from the damages, fear, and worry associated with flooding.

This procedure involves raising the structure (e.g., a building), as described in the previous section on “elevation,” and placing it on wheels. The building is then transported to a new location and placed on a new foundation.

Property owners should consider many factors before deciding to relocate, including the building’s structural soundness and whether there are bridges or other obstructions along the transportation route. During the move of a residential structure, property owners and their families must live elsewhere, perhaps for several weeks, and may need to store furniture and belongings temporarily.

Normally, cost is the major concern associated with building relocation. In addition to paying the moving contractor, the property owner may need to purchase a new lot, build a new foundation, relocate utilities, landscape, and pay for professional services and fees.

FLOODWALLS AND LEVEES (WITH/WITHOUT CLOSURES). Floodwalls and levees are located away from the structure to be protected and prevent the encroachment of floodwaters. They may completely surround the structure or protect only the low side of the property. Unlike other flood proofing measures, a well-designed and constructed freestanding floodwall or levee results in no floodwater forces on the structure itself. Consequently, as long as the floodwall or levee is not overtopped or otherwise failed, the structure is not exposed to damaging hydrostatic or hydrodynamic forces. With these kinds of measures, there is no need to make structural alterations to the building or structure to be protected. These measures require installation of a sump pump to enable seepage water flowing through or under the levee or floodwall, and rainwater falling inside the levee or floodwall, to be evacuated prior to damaging the protected structure.

Floodwalls and levees require periodic maintenance, including the removal of debris from any check valves on pump discharge pipes after each storm and inspection of the sump pump for proper operation. In addition, the property owner will need to inspect levees for signs of erosion, settlement, animal burrows, and trees. Floodwalls need inspection for signs of cracking and spalling. Care must be taken when constructing floodwalls and levees to protect other properties from any adverse impacts, to avoid filling in wetlands, and to maintain regulatory floodways.

While it is possible to design floodwalls and levees for large flood forces associated with major flood protection projects, such flood proofing measures for individual structures are generally restricted to a height of 6 feet or less. This restriction is usually necessary because of limited space, cost, visual concerns, and less complex design analysis.

The most important consideration of all is that property owners who have constructed floodwalls or levees should not have a false sense of security about their property protection. Every flood is different and one that exceeds the design height and overtops the floodwall or levee or breaches the floodwall or levee can happen at anytime. For this reason, the protected area should always be evacuated prior to flooding.

If a floodwall or levee fails due to overtopping, damage to the protected structure will be as great or greater than if no protection had been provided. Additional damage could even result because of the longer time it takes to remove floodwater from the inside of the floodwall or levee once flood levels subside.

Levees. Typically, levees are constructed of compacted fill taken from locally available soils. Depending on the availability of suitable local soils, levees may be one of the least expensive of all flood proofing measures. They are usually built parallel to the river and extend to high ground when it is available. They can also be built to completely surround the structure to be protected. Because they are easy to shape, levees can be made compatible with the landscape. If enough space is available, they can have broad bases and rounded tops to blend in with the surrounding landscape. The property owner can plant grass and other forms of light vegetation on an earthen levee to help prevent erosion and provide esthetic enhancement. Compacted earth can also be placed against a building in lieu of a free-standing levee and pleasingly landscaped. This could be considered a dry flood proofing technique.

Levees have drawbacks that may make them impractical for many property owners. One potential problem is that levees can impede the natural flow of water in a flood plain, possibly resulting in increased flooding of adjacent property. Similarly, they can also block the natural drainage from surrounding property. Another major drawback is that levees take up a considerable amount of property space. To minimize erosion and to provide adequate stability, their embankment slopes must be no steeper than a ratio of one vertical to two horizontal--with a ratio of one vertical to three horizontal preferred. Because of this, a levee’s width will be several times its height.

An important factor in determining the feasibility of a levee involves the availability of suitable fill material for the levee as well as the adequacy of the underlying soil that must support the levee. Most types of soils are suitable for constructing levees. The exceptions are very wet, fine-grained, or highly organic soils. The best soils are those that have a high clay content and therefore are highly impervious. Impervious soils minimize seepage problems either through or under the levee system.

In those cases where suitable fill material is not locally available, the expense of transporting appropriate material to the site can be significant. This additional cost could be a major factor in determining the economic feasibility of this measure. While all levee slopes should have vegetative cover, one way to further protect a levee from erosion is to armor the vulnerable areas with resistant material such as stone riprap.

Floodwalls. Similar to levees, floodwalls also keep water away from the structure being protected. However, floodwalls are constructed of stronger materials and take less space. Floodwalls can be constructed using a variety of designs and materials and can be constructed not only to protect a building but also to enhance its appearance.

Selection of a floodwall design is primarily dependent on the type of flooding expected at the structure site. Large flood depths and high flood velocities create large hydrostatic and hydrodynamic forces that could cause a floodwall to fail by tipping over. High flood velocities, combined with erosive soil, can also cause floodwall failure due to scour beneath the footings of the floodwall.

Closures. Closures must be provided for sidewalks, driveways, and other openings left in a floodwall or levee. However, floodwalls and levees designed without closures are more reliable because there is no need for human intervention to properly install the closure device in the openings. In the case of a levee, access may be provided simply by constructing the levee with gentler sideslopes at the driveway to allow vehicles to enter and exit by passing over the levee. When constructing a floodwall or levee around a structure, a sump pump must be incorporated into the design to provide proper interior drainage of floodwater seepage under or through the levee or floodwall and of rainwater falling on the protected side of the levee or floodwall.

Closures serve to close the openings in floodwalls and levees and prevent water from entering. They can consist of a variety of shapes, sizes, and materials. In some cases, closures are permanently attached using hinges so they can remain open when there is no flood threat. They may also be portable, normally stored in a convenient, nearby location and slipped into place when a flood threatens. There are a number of elements involved in designing and using a closure system. Closures can be separated into two basic categories: permanent or temporary. Combinations of permanent and temporary closures may also be feasible. Permanent closures are those that permanently close openings such as little-used doorways or windows. Temporary closures are those that are put into position to close an opening during a flood event and are then removed and stored away after the event.

Temporary closures can be considered an option only if a flooding situation provides sufficient warning time to properly install them. Both sufficient warning time and "human intervention" are critical to the success of closures since all temporary closure systems require personnel to install them and make certain they are properly sealed.

Closures that are stored between floods must be readily accessible. The effectiveness of an entire system will be compromised if the closures are stored such that flooding renders them inaccessible or if even one closure is improperly installed. Closure systems are most effective where there are a limited number of openings. If there are too many, leakage could overwhelm and defeat the system. Any sewers or drain pipes passing through or under a floodwall or levee will require closure valves to prevent backup and flooding inside the protected area. Care must also be taken to ensure

that backfill material placed to cover utility access under or through a levee or floodwall is properly compacted so floodwater cannot breach the levee or floodwall.

DRY FLOOD PROOFING. Dry flood proofing involves sealing the walls of structures such as buildings with waterproofing compounds, impermeable sheeting, or other materials and using closures for covering and protecting openings from floodwaters. In areas of shallow, low-velocity flooding, closures in the form of shields can be used on doors, windows, vents, and other building openings. The first step in using closures placed directly on buildings is to be certain that both the closure and the building are strong enough and sufficiently watertight to withstand flood forces. To prevent backup and flooding inside a building, sewer lines should be fitted with cutoff or check valves that close when floodwaters rise in the sewer. Utility lines through the flood proofing measure also need to be designed so floodwaters cannot fail the flood proofing measure by following the utility line into the protected area.

Dry flood proofing is not generally recommended for buildings with basements. These types of structures are susceptible to large amounts of hydrostatic force if the ground surrounding the basement becomes saturated with water. This can result in serious damage to the structure due to uplift of the basement floor, collapse of the basement walls, or the entire structure becoming buoyant. Generally, dry flood proofing should only be employed on structures constructed of reinforced concrete, concrete block, or brick veneer on a wood frame. Weaker construction materials will fail at lower water depths from hydrostatic force. Conventionally constructed brick veneer on a wood frame or concrete block walls should not be flood proofed above a height of 3 feet because of the danger of structural failure from hydrostatic forces. Dry flood proofing above this height is not recommended unless the building walls are designed for larger hydrostatic force.

Some waterproofing compounds cannot withstand significant water pressure or may deteriorate over time. For effective dry flood proofing, a good drainage system must be provided to collect the water that leaks through the sealant or sheeting and around the closures to the interior of the structure. These systems can range from small wet-vacuums to a group of collection drains running to a central point from which water is removed by a sump pump. A perimeter drainage system leading to an adequate sump pump or pumps must be installed if an effort is made to flood proof a basement. This is needed in order to reduce hydrostatic force on the basement floor and walls. Property owners considering dry flood proofing should consult a professional engineer to analyze hydrostatic force that can cause structural damage to walls and floors. Though dry flood proofing may seem simple, it is a sophisticated method that requires full understanding of the possible dangers stemming from poor planning, design, or installation. Because it may be difficult to reliably evacuate seepage water and also to refrain from occupying a building during a flood event, this measure may be less easy to satisfactorily accomplish.

Most wall materials, except for some types of high-quality concrete, will leak unless special construction techniques are used. These techniques require a high level of workmanship if they are to

be effective. The most effective method of sealing a brick veneer wall is to install a watertight seal behind the brick when the building is constructed. To flood proof existing brick veneer structures, the best way to seal a wall is to add an additional layer of brick veneer with a seal "sandwiched" between the two layers. It is possible to apply a sealant to the outside of a brick, block, or concrete wall, but any coating must be applied carefully. Cement or asphalt-based coatings are the most effective materials for sealing such walls, while clear coatings such as epoxies and polyurethanes tend to be less effective. As a result, the esthetic advantages of brick veneer walls are lost with the use of better sealant coatings.

The difficulty and complexity of sealing a structure also depend on the type of foundation, since all structural joints, such as those where the walls meet foundations or slabs, require treatment. For very low flood levels, such as a few inches of water, a door can be flood proofed by installing a waterproof gasket and reinforcing the door jamb, hinge points, and latch or lockset and coating it with a waterproof paint or sealant.

If there is a chance of higher flood levels, some type of closure shield will be needed. If the expanse across the door is 3 feet or greater, the shield will have to be constructed of strong materials, such as heavy aluminum or steel plate. The frame for such an installation must be securely anchored into the structure. When windows are exposed to flooding, some form of protection is needed because standard plate glass cannot withstand flood forces. One solution is to brick up all or part of the windows. It may also be possible to use glass block over the windows instead of brick, to admit light. For normal-sized windows, shields can also be used. They should be made of such materials as strong Plexiglas, aluminum, or framed exterior plywood. These can be screwed to the building or slid into pre-designed frame slots in order to cover the windows. Another alternative is to replace the glass with heavy Plexiglas; however, the window must be sealed shut and waterproofed using water-resistant caulking.

WET FLOOD PROOFING. If dry flood proofing is impossible or too costly, another option is wet flood proofing, which allows the structure to flood inside while ensuring there is minimal damage to the building and any contents. Interior flooding allows hydrostatic force on the inside of the building walls to equally counteract the hydrostatic force on the outside, thus eliminating the chance of structural damage. When the structure is designed for wet flood proofing, vulnerable items such as utilities, appliances, and furnaces should be relocated or temporarily waterproofed with plastic bags and sheeting. Utilities and appliances should be moved permanently or temporarily to a place in the building that is higher than a selected flood level--either to an existing area, such as the attic, or to a small addition that could serve as a utility room.

If there is no space for relocating utilities, appliances, and other contents, they may be protected in place. In the case of very shallow flooding, a mini-floodwall built around these items would provide protection. For deeper waters, they could be elevated on platforms or suspended overhead from floor or ceiling joists.

The property owner must have sufficient warning time to employ wet flood proofing methods by temporarily moving items and then to evacuate all personnel prior to flooding. If a building is subject to flash floods, this method will not work. In addition, the property owner must be aware that flooding an area containing a source of electricity or hazardous materials can be dangerous. Also, cleanup will be required after each flood.

The owner of a building that has been wet flood proofed may choose to flood the basement of that building with a clean, potable water source (such as water from a garden hose connected to a faucet) before floodwaters reach the building. This would reduce the amount of contaminated floodwaters entering the structure and would minimize health concerns, cleanup time, and costs.

CHARACTERISTIC ASSESSMENT FOR SUCCESSFUL FLOOD PROOFING

FLOODING CHARACTERISTICS.

Flood Depth. A structure is susceptible to floods of various depths, with floods of greater depth occurring less frequently than floods of lesser depths. Potential flood elevations from significant flooding sources are shown in flood insurance studies (FIS) for communities participating in the National Flood Insurance Program (NFIP) and in other sources of flood plain information. For the purpose of assessing the depth of flooding likely to impact a structure, it is convenient to use the flood levels shown in FIS's, historical flood levels, and/or flood information from other studies and reports. The depth of flooding affecting a structure can be calculated by determining the height of the flood above the ground elevation at the site of the structure.

If a structure such as a building is subject to flooding depths greater than 3 feet, elevating or relocating the structure are the most effective measures of flood proofing. Dry flood proofing is not appropriate because water depths greater than 3 feet may cause hydrostatic force large enough to render structural damage or cause wall collapse unless the building has been designed to accommodate such forces. Flood proofing with levees and floodwalls for depths greater than 3 feet can be undertaken, but it may require devices to control seepage under the levee or floodwall.

If a structure subject to flooding depths less than 3 feet is well constructed by conventional methods, hydrostatic force is not a problem. Therefore, consideration can be given to using barriers, sealants, and closures for flood proofing. If shallow flooding causes a basement to fill with water, wet flood proofing can be used to reduce flood damage. Special devices are available to prevent basement flooding due to water backup through sewers.

Flood Velocity. The speed at which floodwaters move--the floodflow velocity-- is normally expressed in terms of feet per second (fps). As floodwater velocity increases, hydrodynamic forces are added to the hydrostatic forces from the depth of still water, significantly increasing the

possibility of structure failure. Greater velocities can quickly erode or scour the soil surrounding structures. These fast-moving waters can also result in failure by erosion, and their impact may move a structure from its foundation. When floodwater velocities exceed 3 fps and 3 feet of depth, it becomes difficult, if not impossible, for adults to maintain their balance while walking through a flooded area. Unfortunately, there is usually no readily available source of information to determine potential flood velocities in the vicinity of specific structures. Historical information from past flood events is probably the most reliable source. If personal knowledge of past flood erosion and/or movement of structures is not available, others in the neighborhood may be able to provide this type of information. If specific information on flood velocities is available and indicates that the structure is subject to floodwaters with velocities greater than 3 fps, professional advice is critical in the selection of an appropriate flood proofing measure.

Flash Flooding. In areas of steep topography and/or small drainage areas, floodwaters can rise very quickly with little or no warning. This condition is known as flash flooding. High velocities usually accompany flash flooding and may preclude certain types of flood proofing. In a flash flooding situation, flooding usually begins to occur within 1 hour after significant rainfall. If a structure is susceptible to flash floods, insufficient warning time can preclude the use of any flood proofing method requiring human intervention, such as installing closures on windows, doors, or floodwalls. Temporarily relocating moveable contents to a higher level is also impractical. However, these methods can be effective if a building is not subject to flash flooding and the area has an adequate flood warning system and such warnings are broadcast on television and radio or disseminated on a personal basis by local emergency authorities. In areas of long-duration flooding, certain methods such as dry flood proofing may not be as applicable because of the increased chance for seepage and failure due to prolonged exposure to floodwater.

Ice and Debris Flow. In colder climates, chunks of ice from ice breakup can be carried in floodwaters and act as a battering ram, causing serious structure damage. During flood periods with freezing temperatures, ice can also form around the structure. If floodwaters rise and the ice is thick enough and attached well enough to the structure, lifting can occur, causing severe damage. Floodwaters often carry debris, such as boulders, rocks, and trees, that can destroy most flood proofing measures as well as the structure itself. This type of floodflow is called a mudflow, debris flow, or a mudflood, depending on the quantity of sediment/debris in the floodwater.

If a structure is subject to ice or mudflow/debris flow, flood proofing measures involving elevation other than on earthen fill require the services of a professional engineer to ensure that the building structural supports can withstand the impact of ice or debris flow. Dry flood proofing and wet flood proofing measures should not be used if the building is in an area of ice and debris flow. Floodwalls or levees can be used to protect against this type of hazard if properly designed. Relocation is always applicable for mitigating this type of hazard.

SITE CHARACTERISTICS.

Site Location. Coastal flooding is normally caused by such large storms as hurricanes that cause hazards due to waves, storm surge, abnormally high tides, heavy rainfall, beach erosion, etc. Normally, plenty of warning time exists. High tides, coupled with wave action from high winds, often cause damage more severe than that brought on by river or lake flooding. If a structure is subject to coastal flooding, elevation on piles or posts (preferably piles) or relocation are the only feasible flood proofing measures. The destructive force of wave action will generally destroy other types of flood proofing.

Riverine flooding results from heavy or prolonged rainfall, snowmelt, or combined runoff from the drainage area. Hazards from riverine flooding are based on flood depth, flood duration, flood velocity, erosion, and ice and debris. Warning time can vary from minutes to weeks.

Depending on the characteristic of the flooding source and flood, all flood proofing measures are applicable.

Soil Type. Permeable soils, such as sand, are those that allow groundwater to flow freely. If a structure such as a building has a basement and is located on permeable soil, flood proofing measures involving sealants and closures are ineffective because the permeable soil will allow groundwater to increase hydrostatic force on the basement walls, causing seepage and/or structural damage. Water will pass under floodwalls and levees constructed on permeable soil unless seepage control measures are included as part of the flood proofing measure. Other problems with soil that is saturated with floodwaters also need to be considered. If a structure is located on unconsolidated soil, wetting of the soil may cause uneven (differential) settlement. The structure may then be damaged by inadequate support and pulling or bending forces. Some soils may expand when exposed to floodwater and cause forces against basement walls and floors. Thus, serious damage can occur even though floodwaters do not enter the structures.

STRUCTURE CHARACTERISTICS.

Structure Foundation. There are three basic types of foundations for structures such as buildings which may be utilized individually or in various combinations. They are slab-on-grade; crawl space with the structure supported on extended foundation walls, piers, posts (columns), or piles; and basements with poured concrete walls and floors or masonry walls and poured concrete floors. Each type of foundation has its own advantages and limitations when flood proofing measures are being evaluated. All types of flood proofing can be considered for slab-on-grade foundations and crawl spaces on extended foundation walls. However, the crawl space foundation generally provides for more economical elevation and relocation flood proofing measures. Structures with basements require more involved flood proofing measures and are generally not recommended for flood proofing.

Structure Construction. Most structures are constructed of concrete and masonry or wood. However, other materials such as steel, aluminum, vinyl, and fiberglass are also used. Combinations of these materials may be used in the construction of a single structure. Thus, the suitability of applying a specific flood proofing measure can be difficult to assess. Concrete and masonry construction can be considered for all types of flood proofing measures. When classifying construction as concrete and masonry, it is important that all walls and foundations be constructed of the material. Otherwise, there may be a weak link in the flood proofing measure, resulting in potential for failure.

Structure Condition. Structure condition may not be easy to evaluate, as many structural defects are not readily apparent. However, careful inspection of the property should provide for a classification of “excellent to good” or “fair to poor.” This classification is only for the reconnaissance phase of selecting an appropriate flood proofing measure(s). More in-depth investigation and design may alter the initial judgment regarding building condition and eliminate consideration of some flood proofing measures.

FLOOD PROOFING MATRIX

A flood proofing matrix (Figure 1) has been included in this report to better understand the relationship of flood characteristics, site characteristics, and structure characteristics to the applicability of particular flood proofing measures. The matrix serves to summarize the information presented in this chapter.

**Instructions for using the
 FLOOD PROOFING MATRIX**

- STEP 1 Select the appropriate row for each of the nine characteristics that best reflects the flooding, site, and building structure characteristics.
 - STEP 2 Circle the N/A (not applicable) boxes in the rows of characteristics selected.
 - STEP 3 Examine each column representing the different flood proofing measures. If one or more N/A boxes are circled in a column representing a flood proofing measure, that alternative should be eliminated from consideration unless special features (as footnoted) are applied to overcome the N/A concern.
 - STEP 4 Test the flood proofing measures that do not have circled N/A boxes for compliance with your community’s flood plain management ordinance and building permit requirements.
 - STEP 5 Flood proofing measures that would be in compliance with community requirements should now be further evaluated for economic, aesthetic, risk, and other considerations. A preferred measure should evolve from this evaluation.
 - STEP 6 Obtain professional engineering and construction services for detailed design and implementation of the preferred flood proofing measure. Professional advice may rule out the preferred measure, and an alternate measure will need to be selected.
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- N/A² Dry flood proofing can work with these depths if the walls and floor are designed to resist the hydrostatic force and if the structure is designed to not become buoyant.
 - N/A³ Space and aesthetics usually limit levee and floodwall heights for flood proofing to 6 feet. However, from an engineering viewpoint, greater heights are common.
 - N/A⁴ Hydrodynamic force directly on the structure eliminates this measure.
 - N/A⁵ Scour due to fast flood velocity eliminates this measure.
 - N/A⁶ Flash flooding does not allow time for human intervention; thus, these measures must perform without human activity involved. Openings in foundation walls must be large enough to equalize water forces and should not have removable covers. Closures and shields must be permanently in place, and wet flood proofing cannot include last-minute modifications.
 - N/A⁷ Permeable soils allow seepage under floodwalls and levees; therefore, some type of cutoff feature would be needed beneath structures. Permeable soils also allow hydrostatic force to directly affect the structure; therefore, the walls and floor must be designed to resist hydrostatic force and buoyancy.

