

Guidelines for Management of Flood Protection Works in British Columbia



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Guidelines for Management of Flood Protection Works in British Columbia

This document has been prepared to consolidate and summarize current practice respecting the management of flood protection works in British Columbia. The purpose is to assist Diking Authorities and flood protection professionals in fulfilling dike safety requirements as legislated under the British Columbia *Dike Maintenance Act*.

Standard dike management includes a range of activities aimed at ensuring flood protection works are repaired and well maintained, and that advance preparations are made to protect public safety during flood events. In brief, this means implementation by a local diking authority of a continuing funded program including provision for periodic inspection, performance monitoring, operation, repairs and maintenance, contingency emergency planning, and

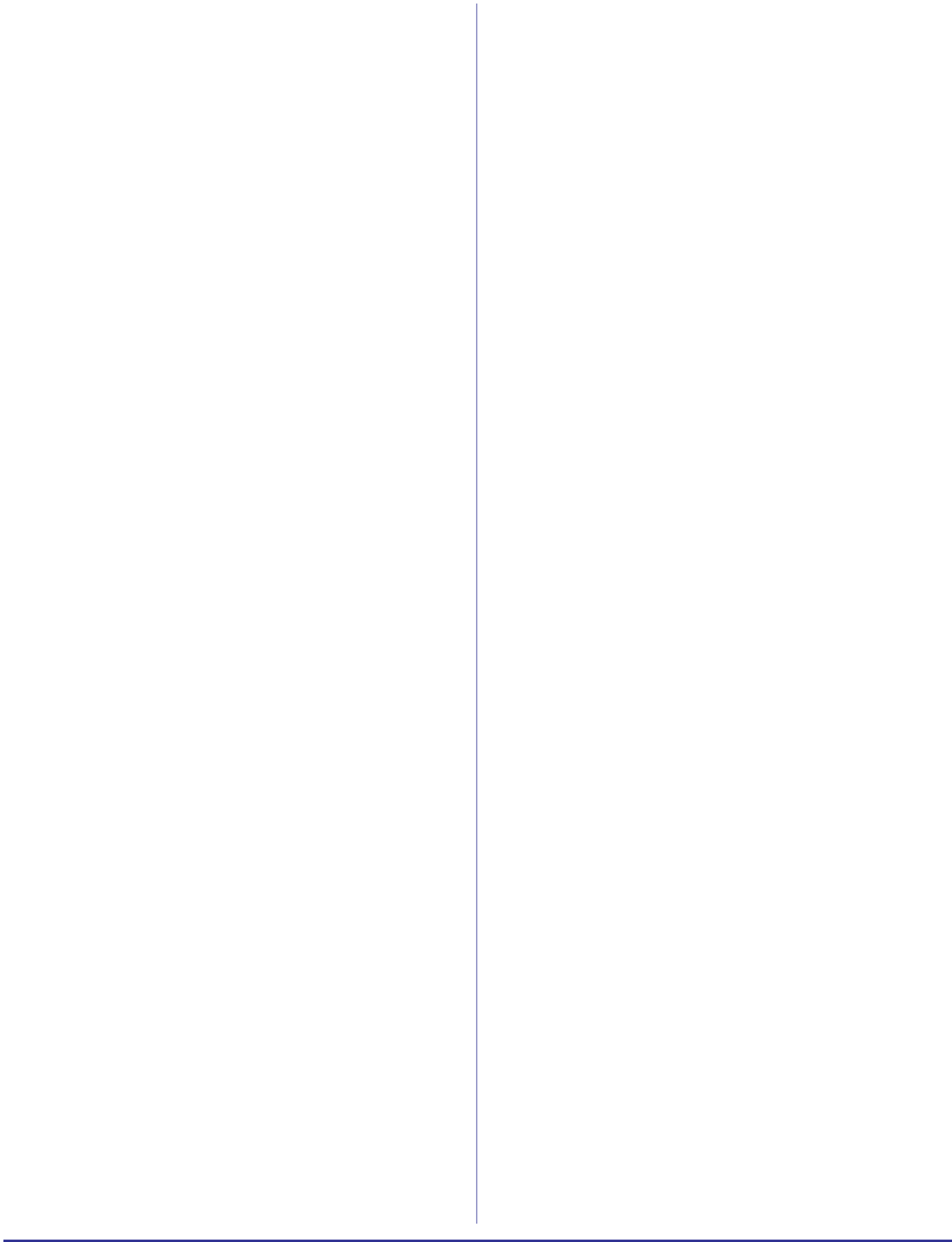
flood patrol and response all in accordance with the system Operation and Maintenance Manual.

While information regarding standards as well as operation and maintenance have been incorporated into this document, it is in a generalized form only. Application of principles require system specific instructions and expert advice.

Comments regarding any aspect of this document or about flood protection issues in the province may be directed to the office of the Inspector of Dikes or the regional Deputy Inspector of Dikes.

P.J. Woods, P. Eng.
Inspector of Dikes

March, 1999



1. General

This document consolidates and discusses current general guidelines for management of flood protection dikes in British Columbia to meet standards of management of flood protection works as administered under the *Dike Maintenance Act*.

1.1 Definitions

Definitions from the *Dike Maintenance Act*

“dike” means an embankment, wall, fill, piling, pump, gate, floodbox, pipe, sluice, culvert, canal, ditch, drain or any other thing that is constructed, assembled or installed to prevent the flooding of land;

“diking authority” means

- (a) the commissioners of a district to which Part 2 of the Drainage, Ditch and Dike Act applies,
- (b) a person owning or controlling a dike other than a private dike,
- (c) a public authority designated by the minister as having any responsibility for maintenance of a dike other than a private dike, or
- (d) a regional district, a municipality or an improvement district;

“improvement district” means an improvement district within the meaning of the Municipal Act;

“inspector” means the Inspector of Dikes referred to in section 2 and includes the Assistant Inspector of Dikes;

“municipality” means a municipality as defined for the purposes of the Municipal Act;

“order” includes a decision or direction of the inspector;

“private dike” means a dike built on private property without public funds to protect only the property of the person owning the private dike.

1.2 Flooding in British Columbia

Flooding in British Columbia is caused by a variety of natural conditions which depend largely on the size and geographic location of the water body. The nature of flooding may also be modified by natural and changes in the watershed, as well as the presence of dams and/or diversions, bridges and other structures.

The Water Survey of Canada maintains records of water levels and/or flows on major watercourses in the province and the Canadian Hydrographic Service records sea level measurements at various locations along the coast. The appropriate records should be referred to and analyzed to appraise local conditions.

Freshet flooding is used in this document to refer to spring snowmelt runoff which is influenced by annual winter accumulation of snowpack, and specific temperature/rainfall conditions in the spring period. Snowpack accumulation/ depletion and conditions are monitored and reported on in periodic *MELP Snow Survey Bulletins*. Freshet flooding is capable of affecting large areas of the province (as was the case in the springs of 1894 and 1948 which affected floodplain areas within virtually the entire southern half of the interior of the province).

Flash flooding may occur locally particularly on small to moderate sized streams throughout the province due to spring, summer, or fall/winter rainstorms. Coastal streams of all sizes commonly rise rapidly to their greatest annual peaks during intense fall and winter rainstorms.

Flooding from the ocean is influenced by tides and **storm surge** which raises sea level due to barometric pressure effects and wind. A particularly sensitive period occurs if a storm coincides with spring tides (the annual tide cycle peaks around the equinox in December and June).

The outer coast (including deep fjords), is also infrequently affected by **tsunami** (tidal waves). These are water level changes caused by tectonic activity,

and/or landsliding and may occur at any time of year. Pacific tsunami events are monitored by the International Tsunami Warning System which issues “watches” and “warnings” as required. In British Columbia, response is guided through the Provincial Emergency Program by the British Columbia Tsunami Warning Plan. While several hours warning may be available for remotely generated tsunami there may be little or no warning of those locally generated.

Local effects will vary depending on local aspect and conditions as well as tide levels coinciding with arrival of a series of tsunami waves.

The majority of flood protection works in British Columbia are designed to protect against riverine and/or ocean flooding. There are currently no flood protection works in the province designed specifically to protect against tsunami occurrence.



2. Legislation and Regulatory Controls

Regulatory controls on construction of new flood protection works and related maintenance is fundamentally within the purview of the *BC Dike Maintenance Act*. Legislation relevant to the formation and operation of diking authorities includes the *Drainage Ditch and Dike Act*, the *Diking Assessment Act*, the *Diking Assessment Adjustment Act*, the *Drainage and Diking Adjustment and Repeal Act* and the *Municipal Act*. Other pertinent provincial legislation includes the *Emergency Management Act*, *Municipal Act*, *Water Act*, *Land Act* and, in the case of review of proposed major projects, the *Environmental Assessment Act*. Relevant federal legislation includes the *Canada Fisheries Act* and the *Navigable Waters Protection Act*.

Construction of works and maintenance may also be subject to other municipal, provincial, and federal legislation and regulations, as well as local *bylaws* and *zoning*. A list of agencies involved in or concerned about flood protection works is included in Appendix D.

2.1 Dike Maintenance Act

The principal legislation in BC pertinent to flood protection works is the *Dike Maintenance Act*. Section 2(4) of the Act provides that works in and about flood protection dikes shall be subject to written approval by the Inspector of Dikes. This includes:

- anything that may lower or decrease the size and/or integrity of the cross-section of a dike.
- installations of floodboxes, culverts, pipes or any structure in a dike.
- construction of works over or on a dike right of way.
- alterations to the foreshore adjacent to a dike.

Any proposal for construction of new flood protection works, as well as activities on, through or adjacent to existing flood control works must be approved in writing by the regional Ministry of Environment, Lands and Parks (MELP) Deputy Inspector of Dikes

(DIOD) prior to implementation. An application, including drawings and written description of the proposal, must be submitted for review well in advance of proposed construction.

2.2 Water Act

All work in and about streams or other watercourses is subject to approval or regulation under Section 7 of the *Water Act*. The Regional Water Management office of the MELP should be consulted as to the approval process for all projects which necessitate activity within the natural boundary of a watercourse. (FREMP approval for the Fraser River Estuary substitutes for Water Act Approval in that locale.)

2.3 Canada Fisheries Act

The Federal Department of Fisheries and Oceans (DFO) is responsible, under the Fisheries Act (R.S.C., 1985, c.F-14), to protect fish and fish habitat in and about “waters frequented by fish.” This includes protection from any work in or near these waters. Pacific salmon are a federally-managed resource.

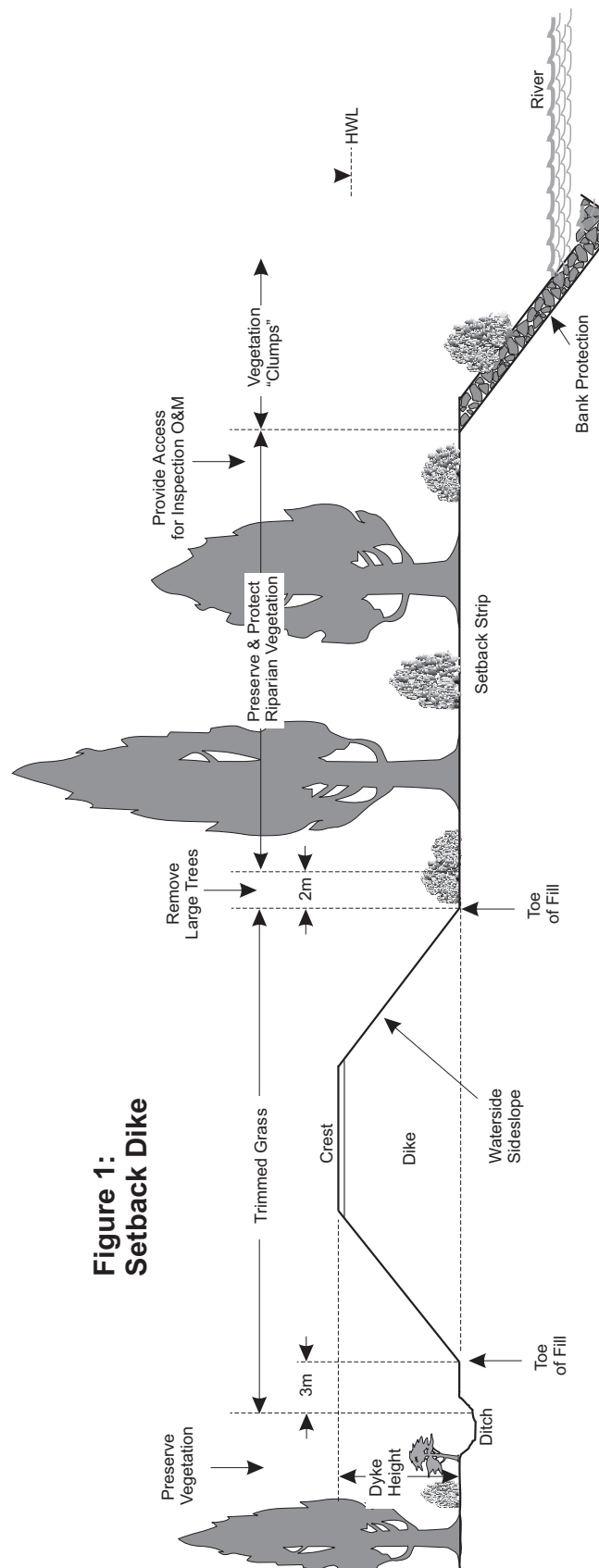
The MELP Fish and Wildlife is responsible for management of steelhead, trout, char and other non-salmonid freshwater species under the Fisheries Act.

All works or vegetation removal in or adjacent to waters containing fish or fish habitat, whether marine or fresh water, require approval under the *Fisheries Act*. This will involve Canada Fisheries and Oceans in salmonid bearing streams and waters, and, in all cases, MELP Fish and Wildlife.

2.4 Land Act

The *BC Land Act* affects the removal of gravel from streambeds. Where the streambed is on Crown Land, MELP Water and Lands is the lead agency in terms of gravel removal, which may be subject to royalty. There may also be privately owned streambeds where the landowner must be dealt with. (Note that other

**Figure 1:
Setback Dike**



applicable legislation applies to both publicly and privately owned streambeds.)

2.5 Forest Act

In all cases the Ministry of Forests must be consulted as to the approval process for removing merchantable trees and wood from streambeds and banks.

2.6 Canada Navigable Waters Protection Act

Works within, above or under the wetted perimeter of navigable waters will be subject to review under the *Navigable Waters Protection Act*.

2.7 BC Environmental Assessment Act

Major projects are subject to environmental review under the *Environmental Assessment Act*. Regulations are currently under development but initial indications are that this would include construction of new dikes as well as raising the entire length, dismantling, or abandonment of existing structures, if protecting an area greater than ten square kilometers.

2.8 Municipal Act

The *Municipal Act* provides for the formation of Improvement Districts (Section 822 (1965)) for purposes designated in their Letters Patent. While there are 19 Improvement Districts which are now involved in diking, this legislation is not used for formation of new diking authorities for new flood protection systems. The accepted mechanism for authorizing new diking authorities is under Section 585 (1960) of the *Municipal Act* which provides that local governments may, under local bylaw, undertake or regulate diking and drainage works within their jurisdiction.

2.9 Emergency Program Act

The *Emergency Program Act* regulates emergency management in the province of BC. Section 6.(3) of the Act states that:

A local authority...must...establish and maintain an emergency management organization to develop and implement emergency plans and other preparedness, response and recovery measures for emergencies and disasters...

2.10 Other legislation

The *Drainage, Ditch and Dike Act*, passed in 1907 (consolidated 1990), provided the authority to fund and construct works for draining lands for mines, manufacturing, and for municipalities or Districts to be formed for that purpose. *Part 1* of the Act is no longer in use while *Part 2* is the regulatory basis for incorporation of five diking districts (Fortune Creek DD, Surrey DD, Colebrook DD, Barnston Island DD and Coquitlam DD).

The *Diking Assessment Adjustment Act (1905 and 1947)* regulates adjustments to diking assessments.

The *Diking Authority Act*, passed prior to 1965 and consolidated in 1989, was **not proclaimed**. The intent of the Act was to authorize the formation of diking authorities to undertake diking works.

The *Drainage and Diking Adjustment and Repeal Act, 1965, SBC 1965, c. 96* allows the Lieutenant Governor in Council to repeal by proclamation a number of Acts related to diking and local diking districts. The Lieutenant Governor in Council is also empowered to dissolve any development district.

The *Riverbank Protection Act*, (administered by the Ministry of Transportation and Highways), formerly facilitated an application by a majority of landowners, to undertake a study which shall establish local and other cost- sharing and/or a tax levy, and to implement flood protection works. The act is currently not in use.

3.

Approvals and Controls Under the *Dike Maintenance Act*

Works on, as well as changes in and about existing flood protection works must be submitted to the MELP regional Deputy Inspector of Dikes (DIOD) for prior review and written approval. This includes any works that potentially impact on dike safety (whether on or off dike right of way). Proposals for new flood protection must also be referred for review.

A technical review is made to ensure that provincial standards are met, that the protection afforded by existing flood protection works is not compromised, and that detrimental effects do not occur to river processes or other parties. Certain measures including construction techniques, temporary works, seepage control, and time of year restrictions may be imposed to assure the integrity of flood protection.

The diking authority must also work with local government to control development or construction on, through or in the vicinity of the flood protection works, to ensure that the standard of flood protection is not diminished. Development and activity within protected areas should be in accordance with accepted floodplain management practice as established by the Regional Water Manager and administered by local government through zoning, bylaws, etc.

3.1 *General*

- reasonable options shall be adopted where practical to avoid construction on through, or near flood protection dikes.
- works potentially affecting public safety shall be certified by a suitably qualified Professional Engineer.
- temporary measures shall be provided to ensure that flood risk is controlled.
- works shall be planned and scheduled to ensure that the protection is not diminished during potential flood periods.

- works shall be planned and constructed with due regard for environmental needs.

3.2 *Utilities, pipes and cables in flood protection dikes*

- pipes, gas pipelines, waterlines, sewer lines, etc. shall preferably be installed by a cut and cover method, backfilled with relatively impervious compacted material and provided with seepage collars, as applicable.
- rupture resistant pipe, with mechanical or equivalent joints that will not separate under settlement or deformation shall be used in the dike section.

3.3 *Dike crest and slopes*

- access to flood protection dikes and associated structures for operation and maintenance (O&M) purposes shall not be impeded.
- cross fences shall be gated to not impede access along the dike crest for inspection and/or maintenance purposes.
- no permanent structures other than those associated with flood protection shall be placed on dike fills. (Exceptions may be made for compatible water resource structures.)
- landscaping and vegetation on dikes and bank protection is generally discouraged (other than grass or approved low ground cover) unless in accordance with current “Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment”.

3.4 *Excavations*

- excavation adjacent to dikes, bank protection or other flood protection structures should be avoided, but where necessary, expert advice

should be obtained to ensure that the excavation is compatible with stability of the works.

3.5 Dredging

- dredging shall not take place in any location that would tend to undermine or threaten the stability of the dike or bank protection.
- riverside excavation should generally not be undertaken within 10 meters of the toe of riprap nor extend below a 3 horizontal: 1 vertical slope from the dike crest.

3.6 Marinas and docks

- structures shall be designed to minimize opportunity for flow deflection, trapping of debris or ice, or other effects that may affect the stability or safety of the flood protection works.
- provision shall be made to prevent erosion by boat wash, or waves or other effects caused by structures, their operation or use.
- docks and structures shall not obscure the dike slopes or bank protection without adequate provision for inspection access and repairs.

3.7 Landside encroachment

- construction on the landside of a dike shall not interfere with operation and maintenance activities. Generally, neither buildings or other permanent structures shall be allowed closer than 7.5 m from the landside toe of a dike or as required from other flood protection structures.
- where permitted, landfill placed against the landside slope of a dike shall be to the same standards as dike fill and shall not interfere with seepage control measures nor cause detrimental effects such as settlement of the dike.

- landside construction shall not interfere with internal drainage courses.

3.8 Bridges and stream structures in diked areas

- bridges and similar works shall be situated, designed and constructed to minimize opportunity for blockage, diversion, redirection or change in velocity of flows, scour, sedimentation and/or interference with access for operation and maintenance of flood protection works.
- abutments and piers shall be founded on piles or piers extended below river scour levels and protected against erosion and scour.
- detrimental backwater effects, head losses, changes in flow direction or velocity shall not be caused at the flood protection design flood flow.
- the underside of a bridge shall generally have a minimum clearance of 1.5 m above the higher of the calculated peak instantaneous 1:200 year level or flood level of record (or higher where required for ice or debris passage).

3.9 Roads and accesses

- dikes are generally not used for public vehicle access and roads. Where roads or recreation trails are incorporated into or form part of flood protection works, care shall be taken to ensure that road maintenance work, repairs etc. do not compromise the level of protection.
- the dike crest, roads and accesses shall be graded, graveled and maintained in a condition suitable for inspection, emergency vehicles and heavy equipment in support of operation and maintenance.

4.

Standards For New Flood Protection Works

Construction of new flood protection works will generally require inter-agency review and approval to meet the various legislative needs. The essential aspects of British Columbia standards for flood protection works administered under the *Dike Maintenance Act* are summarized as follows:

- design and construction for efficient and effective operation to contain the design flood* and associated forces.
- certification of works by a suitably qualified professional engineer.
- provision of permanent rights of way, accesses and means of operation and maintenance.
- implementation by a local authority of a continuing funded dike management program including inspection, patrolling, emergency planning, operation, maintenance and repairs in accordance with an approved Operation and Maintenance (O&M) manual.

* The **standard design flood** in British Columbia is the “designated flood” which “means a flood, which may occur in any given year, of such magnitude as to equal a flood having a 200 year recurrence period interval, based on a frequency analysis of unregulated historic flood records or by regional analysis where there is inadequate streamflow data available. Where the flow of a large watercourse is controlled by a major

dam, the designated flood shall be set on a site specific basis.” (Reference: MELP Procedure Manual 06-09-04.07).

The criteria was originally based on the 1894 flood event which affected a broad area of southern British Columbia as the largest flood recorded in modern times. (Estimates of the return period for this flood vary depending on gauge analyzed and period of record but it falls in the range of about 1:160 to 1:200 years.)

The adopted standard for the Fraser River Flood Control Program (FRFCP) is generally the adjusted 1894 Fraser River profile (variations locally relate to 1948 highwater marks, and adjustment of the high water profile by backwater calculation accounting for the effects of dikes on overbank flow). The design levels for the FRFCP sea dikes were determined by statistical analysis of coastal gauge records to determine a 1:200 year water level with addition of an allowance for waves and runup.

Elsewhere in the province, consistent with the BC Floodplain Development Control Program, the standard design flood is the “designated flood” being the computed statistical 1:200 year return period flood. It should be noted that other relevant standards for older dikes and farm protection works include the use of a flood of record and other criteria that represent the “standard of the day”.

5. Management of Flood Protection Works

5.1 Responsibilities

The **Diking Authority** is responsible for all local flood protection management considerations including: periodic inspection; performance monitoring; operation; repairs, maintenance, and replacement; contingency emergency planning; dike flood patrol and emergency measures.

The office of the **Inspector of Dikes**, under authority of the *Dike Maintenance Act* is responsible for overall administration of the provincial dike safety program, and the establishment of standards, policy, procedures and regulations for the Province of British Columbia. The regional MELP **Deputy Inspectors of Dikes** (DIODs) form the operational contacts for diking authorities, and are responsible for approvals, auditing and monitoring, and regional advice regarding dike management.

Monitoring and auditing of the diking authority flood protection management program by the DIOD generally occurs through:

- examination of documentation of the diking authority's operation and maintenance procedures, plans and drawings.
- review of annual inspection reports prepared and submitted by the diking authority.
- review and approval of applications to make changes in and about flood protection works, or construct new works.
- monitoring through personal communications, periodic site visits and spot checks.
- periodic auditing by examination of written and financial records, and joint inspections with the local operation and maintenance supervisor.
- inspection and appraisal of major flood occurrences, and flood damages/major repairs.

monitoring: occurs on an ongoing basis by maintaining an up-to-date contact list, reviewing approval applications, making periodic telephone

contact, and undertaking occasional spot inspections of repairs or areas of interest together with the maintenance supervisor.

auditing: occurs periodically on a less frequent basis and/or as required including: review of monitoring documents, examination of the diking authority's records and financial statements, and joint inspection of key facilities and problem areas.

compliance: is met by progressive actions as required: reminder by telephone, written direction from the DIOD and finally, referral of the matter to the IOD for review and possible issuance of an order as provided by Section 3 of the *DMA Act*.

5.2 Dike management

Standard dike management includes a range of activities aimed at ensuring flood protection works are repaired and well maintained, and that advance preparations are made for the occurrence of flood events. In brief this means implementation by a diking authority of a continuing funded program including provision for periodic inspection, performance monitoring, operation, repairs and maintenance, contingency emergency planning, and dike flood patrol/response all in accordance with an approved Operation and Maintenance (O&M) manual.

5.3 Operation and Maintenance Manuals

Specifics for operation and maintenance for each flood protection system must be documented in an approved O&M manual. The manual should:

- assign responsibilities;
- identify the nature of flood threat and standards of works;
- give a brief flood history and reference flood records;
- discuss general and specific maintenance needs;
- outline inspection needs and frequency;

- outline emergency planning needs and emergency procedures;
- identify system water level gauges, bench marks, monitoring systems;
- include as-constructed plans, right of way plans, etc.;
- provide a bibliography of reference documents such as design reports;
- contain lists of concerned agencies, designers, and contractors.

5.4 Inspection of flood protection works

It is the responsibility of the diking authority to conduct routine and periodic inspections of flood protection works as required and submit these to the regional MELP DIOD.

5.4.1 Annual inspections

At least once a year the entire diking system should be inspected in detail by the diking authority for need of routine maintenance. This inspection should be scheduled prior to the high flow season, and early enough to allow adequate time for any required work to be completed prior to possible flood events.

The inspection should note and record any conditions that might affect the performance or operation of the flood protection system including:

- access, obstructions to the dike and along the dike crest including the condition of all fences, gates, locks and the availability of keys;
- the extent of vegetation growth and any trees that affect visibility of the slopes or that may weaken the dike or bank protection;
- low spots along the dike crest;
- animal burrows;
- sloughing, cracking or damage to the slopes of dike and bank protection;
- signs of erosion of the riverbank or damage to the existing bank protection; particular attention should be given to:

- loss or disturbance of rock from the existing protective layer;
- weathering or abrasion of rock particles;
- slumping of the slope;
- scour at the toe of the slope;
- erosion or scour of the riverbank upstream, and downstream;
- erosion or significant changes to overbank areas.
- structural and functional condition of pumps, pump stations and seepage control works including debris, sedimentation or other problems at intakes, outlets and trash racks;
- the condition of floodbox flap gates and their ability to open and close freely providing a watertight seal;
- condition of scour or erosion around bridges and similar structures;
- damage to, reference level, and visibility of water level gauges and monitoring devices.
- unauthorized excavation or construction in, on or adjacent to the dike;

A written report (which may take the form of field notes using the Dike Inspection Report form in Appendix E, or similar) on the results of the annual inspection should be prepared and a copy submitted to the regional MELP DIOD. Photos of damage or problems may be included. Arrangements must be made by the diking authority for additional investigation, design and approvals as required to ensure necessary work is completed prior to the next high water period.

5.4.2 High water patrol inspections

Patrol inspections should be carried out during floods and high water events as discussed in Section 7 Emergency Measures to monitor the performance of the flood control works and take corrective action as required.

5.4.3 Post-flood inspections and evaluations

An inspection of the protective works should be undertaken after flood events, and particularly when damages occur to works, after water levels have subsided. There may be a need for professional evaluation, design and correction of major damages. (It is noted that successive floods can occur where summer or winter rainstorms provide the primary mechanism for flooding so there may be an element of urgency to assess and correct deficiencies.)

Efforts should be made to locate and record a complete high water profile along the dike after significant flow events. This information should be utilized to assess the dike crest level and freeboard.

5.4.4 Special inspections

Special inspections may be needed at other times of the year to monitor and react to particular situations such as storms, earthquakes, stream channel

sedimentation, debris accumulations and/or ice jamming.

5.5 Operation and maintenance of flood protection works

Approvals must be obtained from the regional MELP DIOD and other authorities as required before commencing major repair work on dikes or when working within the wetted perimeter of the water body.

5.5.1 Dike maintenance/repair

Essential dike maintenance and repair activities are guided by inspection observations and include the following:

- All fences and gates should be kept in good condition. All locks for gates should be in good working order, with keys readily available at all times. It is recommended that vehicular access to



dikes generally be restricted to authorized vehicles where possible unless designated as public roads. There should to be no obstacles which prevent access by authorized vehicles.

- The dike crest profile should be periodically restored by addition of crushed gravel surfacing, as required to maintain a reasonably smooth and competent driving surface.
- Vegetation on the dike fill side slopes should consist of closely trimmed grass or low ground cover. Depending on local growth rates, dike slopes should be cut at least once annually. Trees and brush growth should be removed, in accordance with approved environmental guidelines for dike maintenance.
- Animal holes or burrows in fills should be excavated and backfilled with suitable compacted material. Trapping and/ or relocation of animals may be advisable after consultation with regional MELP Fish and Wildlife.

- Damage to dike slopes should be repaired as soon as possible by the addition and compaction of appropriate clean earth fill materials to restore the slope to original condition.
- Water level gauges and monitoring devices should be inspected annually, repaired and re-leveled if necessary, so that they can be readily observed by dike patrol and/or inspection personnel at all times. Care should be taken to ensure that the gauges are always maintained to the correct datum.

5.5.2 Bank protection maintenance and repair

Bank protection often comprises angular pieces of blasted rock placed over a granular filter layer and/or geotextile. The design for rock gradation and maximum size is determined by the stream velocity, debris and ice conditions, and slope of the bank. The bank protection will require varying maintenance



depending upon the degree and frequency of exposure to stream flow, wave action, floating debris and/or ice.

- Excessive or large growth in bank protection shall be controlled in accordance with current approved environmental guidelines for dike maintenance, to ensure visibility and accessibility for inspection and maintenance, and that large trees do not displace or damage riprap.
- Repair to damaged riprap is commonly made by the addition of suitably graded rock riprap. Riprap should be placed by backhoe, hydraulic excavator, or clamshell to provide a tight interlocking well graded mass forming a smooth continuous slope.

- If a major damages or failure of bank protection occurs, professional engineering advice must be obtained prior to undertaking final repairs, and necessary approvals obtained.

The O&M manual should provide specific requirements for maintenance, repair and replacement of other forms of bank protection such as gabions, lock-blocks, geotextiles, etc. that may be in use.

5.5.3 Floodbox maintenance

Floodboxes allow gravity discharge of internal drainage water from behind the dike into the main watercourse during times when the external water level is lower than the level behind the dike, while preventing backflows when stream flows are high. Floodboxes generally consist of a pipe or culvert



through the dike with a flap gate at the waterside outlet and may have trash racks fitted at the inlet and/or the outlet.

- Maintenance of floodboxes includes cleaning the inlet and outlet of accumulated debris and sediment to ensure water flows freely. The flap gate should be annually cleaned and lubricated to ensure that it swings easily and closes properly with a good seal, and be periodically painted with rust resistant paint.
- The dike slopes adjacent to floodboxes should be kept clear of trees and brush to allow unimpeded inspection of the inlet and outlet of the floodbox.
- Repairs shall be made to erosion and/or undermining of the inlets and outlet structure and sloughing of slopes which might block flows.
- All gates, trash racks and miscellaneous metal parts or works should be examined periodically

for excessive wear or deterioration and replaced as necessary. Metal culvert pipes should be periodically checked internally for blockages, corrosion, collapse and/or deformation.

- Concrete inlet and outlet structures should be inspected for cracking or spalling, and repaired as required. Concrete pipe culverts should be inspected internally for excessive joint movement, loss of joint sealant and leaks at joints, blockages, collapse and/or deformation.
- Floodboxes should be checked regularly in areas where beaver are present since they can block culverts or construct dams very quickly. Culverts should be cleared immediately before the situation becomes more difficult to rectify, and problem animals should be removed.

5.5.4 Pump and pump station maintenance

During periods of high water in the main watercourse, floodboxes close and internal drainage water must then



be either stored or discharged by pumping. There may be permanent or temporary pumping facilities.

- Pump stations must have operation and maintenance manuals specific to each installation.
- Copies of O&M manuals, and Contingency Emergency Plans shall be available in Pump Stations. A list of emergency contact numbers shall be prominently displayed.
- In addition to electrical and mechanical maintenance, debris and sediment monitoring and management is an important consideration at both inlets and outlets of water conveyance structures.
- Pipes should be regularly inspected.
- Supplementary and/or temporary means of pumping may be required during high water periods.

5.6 Performance monitoring

Performance monitoring includes dike patrol inspections, observations and surveys during high water events including records of dike crest profile

surveys, bedload aggradation, downcutting, debris accumulations, etc.

- A complete high water profile along the dike should be recorded during significant flow events to assess the dike crest level and freeboard.
- Records shall be kept of dike crest surveys and comparison to the dike design profile and highwater profiles.
- Areas subject to accelerated bedload aggradation, downcutting or lateral erosion processes shall be identified and may require monitoring by repetitive survey or other means to ensure the integrity and/or capacity of the system is not compromised.
- Areas subject to high debris transport shall be identified and may require periodic monitoring and cleanup.
- Seepage control measures (relief wells, drains, etc.) should be monitored during high water events and records kept of estimated flows and performance indicators such as suspended sediment and backwater conditions.

6. Contingency Emergency Planning

- A flood contingency plan must be prepared and updated annually in conjunction with the local authority (note the *Emergency Program Act* outlines responsibilities of the local authority) in consultation with the Provincial Emergency Program Regional Manager and MELP Regional DIOD.
- Reference should be made to Floodplain Mapping where available, or other information to identify safe zones and areas at risk. Advance provision must be made for dike patrol personnel, and emergency procedures.
- Sources of sandbags and fill material must be identified in advance together with local contractors, materials, heavy equipment, pump and generator suppliers. Required delivery notice, costs and setup times is also valuable information.
- Provision should be provided in the plan for the possibility of uncontrolled failure of flood protection works, including backup measures, and procedures for possible emergency evacuation of the affected population.

7. Emergency Measures

The diking authority must be prepared to carry out any work essential to dike or bank protection integrity as emergency measures. Emergency measures include high water flood patrols, inspections, and implementation of contingency emergency planning and emergency response measures as discussed elsewhere in this document.

The diking authority is responsible for ensuring that there are adequate trained personnel, equipment and materials readily available to patrol the dike and respond to emergency conditions.

Prior to the freshet period, the *BC Snow Survey Bulletin* should be consulted for information regarding predicted runoff volumes and expected peak conditions. Water Survey of Canada gauge records should also be reviewed to appraise timing, duration and magnitude of historical flood events.

Regular monitoring of weather forecasts and storm warnings should be undertaken to assess potential for storm damages and/or flash flooding.

7.1 High Water Patrol Inspections

Patrol inspections should be carried out during high water events to monitor the performance of the flood control works and identify needed corrective actions.

During high water events, local water level gauges should be monitored regularly and the readings recorded for future reference. Dike patrol frequency should increase as flow and/or water levels approach critical conditions, and should be continuous while the level is within about 1.0 m of the dike crest. The patrol crews are to observe and report to the diking authority any conditions or occurrences that could signal a weakening of the works such as:

- Settlement of the dike crest and slopes causing ground depressions or sinkholes. Observations should particularly be made for possible differential settlement over floodboxes and structures in or through the dike.

- Areas of low freeboard due to variable river profile or loss of dike fill.
- Cracking of the dike crest or slopes.
- Gulying: Observations should be made for sloughing and/or erosion of the dike slopes.
- Cables, utilities, pipes, floodboxes, and other structures that transverse the dike fill should be monitored for seepage and settlement.
- Seepage through the dike and/or at the landside toe of the dike. Close attention should be paid to seepage, as the safety of the dike can be threatened by an increase or concentration of seepage flows.
 - Boiling: These are small up-wellings of clear running water caused by excessive seepage pressure and can appear at considerable distances inland from the dike.
 - Piping: Seepage is generally considered to be normal provided flows are not excessive nor concentrated in the form of piping or boils. Piping is the physical transport of fill or foundation material by concentrated seepage flows; this can be identified either as suspended silts (murky water) or visible sand particles. The process results in progressive removal of material with an enlarging hole extending toward the river at an increasing rate. Eventually an open path is created and the dike may collapse and breach in an “explosive” manner. (Piping may be preceded by boils.)
- Relief wells: The rate, colour of flows and transport of particles from relief wells and internal drains should be monitored.
- Pumps not operating properly and need for temporary pumping.
- Erosion of the riverbank adjacent to the dike.

- Sloughing, erosion and/or loss of rock from bank protection works. Critical areas should be closely inspected during and after high water events.
- Debris accumulation at floodboxes, flap gates and trash racks.
- Stream blockages or redirection of flows due to logs, debris, gravel and sediment, and/or ice jams, especially near bridges or other constrictions.

Dike patrol/inspection logs should be retained by the diking authority to record all inspections and actions taken, and also to serve as part of performance records. A sample patrol log is provided in the Appendix.

7.2 *Emergency measures*

As the river rises to critical levels, crews should be prepared to undertake emergency repairs such as treatment of active boiling, excessive slope seepage, riverside erosion, saturation, local overtopping, and pumping of internal drainage.

Emergency procedures must be undertaken with appropriate regard for personal safety and related safety regulations. Advice should be sought from environmental agencies at the time to mitigate detrimental activities.

Professional engineering advice may be necessary for both routine and emergency operation and maintenance.

Local overtopping

- As the prediction of flood profiles is uncertain, and because dikes often have varying freeboard, patrols should be advised to pay close attention to lower than average freeboard.
- Once water flows over a dike crest, fill is usually rapidly washed away creating a breach. This generally increases rapidly in size and will not generally be practical to close until water levels equalize.
- Sandbags are usually considered for raising low sections of dike, however, progress is slow and considerable hand labour is required. Sandbags

should normally only be used for raising short sections. Possible alternatives to sandbags include reinforced plastic sheeting to contain loose granular or other fill, and water-filled dams.

- Heavy equipment and trucks can be used to raise a dike provided the work is done well in advance of high river levels, however, due to possible vibration and saturation effects, heavy equipment is not generally advisable on a dike when the water level is near the crest.

Excessive slope seepage and saturation of fills

- Where seepage on the dike landside slope leads to soggy unstable conditions, free draining fill berms may be needed.
- If high water levels are sustained for extended periods and the dike fills becomes saturated, it may be necessary to restrict traffic on the crest road.

Active boiling

- The simplest and most effective method of treating an active boil (i.e. one that is carrying sand or silt) is to construct a relatively impervious ring around it of a sufficient height to slow flows and stop the transportation of solids. Care should be taken to not build to a height which stops the flow of clear water because this could create excessive local pressure head affecting the dike or causing additional boils nearby. Concrete well rings, short pieces of large diameter pipe, earth berms, sheet steel pilings, etc., can all be used, but the most generally accepted method is using sandbag rings.
- Particular care is needed where the active area is widespread or there is an extensive area of inactive boils at a time of rising water levels.

Riverside erosion

- Where river currents cause erosion of the face of the dike or nearby overbank, rock riprap may be placed with an excavator or end-dumped provided the site is accessible to heavy equipment and safe for operation.

Internal drainage

- Local runoff and drainage will not escape once floodboxes close in diked areas which lack adequate permanent pumping facilities. Temporary pumping of local drainage, or interception and diversion of inflow from higher elevations, may be necessary to alleviate this condition.

Debris/ice/sedimentation

- Dikes are generally designed for open water conditions.
- Accumulations of ice, sediment and/or debris either between floods or during events must be monitored to ensure detrimental deflection of currents and/or blockages do not occur. Action may be necessary to break up and/or remove

accumulations especially at bridges, constrictions and bends.

Emergency warning/evacuation

- Should the possibility of uncontrollable dike failure arise, the local authority and Police (or RCMP) must be alerted immediately in accordance with the local authority contingency emergency plans. Unless directed otherwise by the Police, the diking authority should generally confine its efforts to preventing flooding while ensuring the safety of its workers. The Police would generally be responsible for advice to the public in coordination with the local authority and Provincial Emergency Program (PEP).
- If conditions threaten to exceed local resources, a request for provincial assistance should immediately be directed to the Provincial Emergency Program Regional Manager.

8.

Major repairs, rehabilitation and replacement

Provision must be made by the diking authority to ensure that contingency and replacement funds are accumulated or otherwise available for future repair, reconstruction, rehabilitation or replacement of deteriorated, damaged or otherwise unserviceable structures and works.

Major repairs such as dike and bank protection rebuilding, raising or widening dikes, work which involves breaching of existing dikes, floodbox and pump station replacement, require professional engineering advice. Engineering advice should also be obtained regarding permanent repair work following emergency conditions.

Periodic appraisals should be undertaken by a suitably qualified professional engineer to assess the level of confidence of the works and possible need for improvements or rehabilitation. At least once every 10 years the dike crest profile should be surveyed and compared to both the design profile and high water profiles (this may be required more often if the crest is used as a road surface, has sensitive foundations, or other special conditions).

Approvals required for major repairs and rehabilitation include written approval under the *Dike Maintenance Act*, and other pertinent legislation, bylaws etc. as discussed in Section 2.

9. Records

Records shall be kept by the diking authority to insure complete information is available for future operation, maintenance and repairs, or for audit by the regional MELP DIOD including:

- Operation and Maintenance Manual(s).
- Drawings and plans of the works together with revisions, additions, etc.
- Engineering reports.
- Emergency Response Plan and updates.
- Inspections.
- Patrol logs and records, gauge readings, high water mark profile surveys and other performance data.

- Approval documents and correspondence.
- All cases of damage and repairs with location, cause, repairs effected, dates and times, and photographs, if possible.
- Performance monitoring records.
- Right of way plans, easements, permissions to enter.
- Financial auditor reports (where applicable).

Copies of annual inspection reports should be submitted by the diking authority to the regional MELP Deputy Inspector of Dikes.

10. Appendix

Flood Protection Works Management Checklist

Flood Protection Inspection Report

Dike Patrol Log

Flood Protection Works Management Checklist

Diking Authority: _____

O&M Supervisor: _____

Tel: _____ Fax: _____

DIOD _____

Tel: _____ Fax: _____

Dike Name: _____

O&M Manual: ☐ Yes ☐ No

Floodplain Management Bylaw: ☐ Yes ☐ No

1. Records:

Design Reports _____

Plans _____

Files Nos. _____

Floodplain Maps _____

2. **Rights-of-way:** ☐ Yes ☐ No

3. **Annual Budget/Taxes:** ☐ Yes ☐ No

4. Follow-up Last Inspection

By: _____

Annual Inspection

(submit report to DIOD): ☐ Yes ☐ No

5. **Approvals/Changes:** ☐ Yes ☐ No

6. **Maintenance:** Required Okay

Access: ☐ ☐

gates ☐ ☐

dike crest ☐ ☐

Damages/Repairs: ☐ ☐

dike ☐ ☐

bank protection ☐ ☐

floodboxes ☐ ☐

pumps ☐ ☐

drainage ☐ ☐

Vegetation Control: ☐ ☐

animal activity ☐ ☐

debris ☐ ☐

7. Flood Response Plan:

Flow Forecasting ☐ ☐

Contact list ☐ ☐

Materials ☐ ☐

Equipment ☐ ☐

Communications ☐ ☐

Flood Patrol ☐ ☐

Warning/Evacuation Plan ☐ ☐

8. **Follow-up Action Complete:** ☐ Yes ☐ No

Date: _____

Signed: _____

Flood Protection Inspection Report

Dike Length: _____

DIKE: _____

REACH: _____

DATE INSPECTED: _____ Signed _____

The condition of the flood protection works is as reported below:

1. DIKES: (access, gates, locks, vegetation growth, gravel surface, height, slopes, erosion, animal burrows seepage, trash, berms, relief wells)

2. BANK PROTECTION: (loss of rock, settlement, slumping)

3. FLOODBOXES/PUMP STATIONS: (inlet and outlet channels, gate operation, trash racks, debris, erosion, corrosion, structure, discharge structure, electrical and mechanical components)

4. WORK REQUIRED:

5. ADDITIONAL INFORMATION (attachments, sketch, photos, etc.)

6. WORK COMPLETED: Date: _____ Signed: _____

Submit Inspection Report annually to regional Deputy Inspector of Dikes

Refer to system Operation & Maintenance Manual

Dike Patrol Log

Date: _____ Inspector: _____

Time Commenced: _____ Time Completed: _____

1. Gauge Height	Design WL	Time	Water Level
Gauge _____	_____	_____	_____
Gauge _____	_____	_____	_____

2. Landside Seepage			Comments/Location
Boils	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Clear: _____ Dirty: _____ Piping: _____
Ponding	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____

3. Landside Slope			
Cracking	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Sloughing	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Seepage	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____

4. Dike Crest			
Accessible	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Cracking	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Settlement	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Freeboard	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Sinkholes: _____

5. Riverside Slope			
Erosion	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Dike Fill: _____ Riprap: _____
Instability	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____

6. Floodboxes			
Gates	Open <input type="checkbox"/>	Closed <input type="checkbox"/>	Leakage: _____ Flow Estimate: _____

Pumps			
Inlet/Outlet			Open: _____ Obstructed: _____
Operating	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Flow Estimate: _____

7. Other:			
Wood Debris	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____
Gravel Deposits	Yes <input type="checkbox"/>	No <input type="checkbox"/>	_____

8. Required Action: _____

Notification: _____ To Whom: _____ Time: _____

Refer to system Operation & Maintenance Manual