REPORT ON

SOUTH EAST KELOWNA
IRRIGATION DISTRICT
DAM AUDIT

KELOWNA, BRITISH COLUMBIA

Submitted to:
South East Kelowna Irrigation District
P.O. Box 28064
RPO East Kelowna
Kelowna, BC
V1W 4A6

DISTRIBUTION:

2 Copies - South East Kelowna Irrigation District
1 Copy - Golder Associates Ltd.

September 30, 2004
EXECUTIVE SUMMARY

As requested, Golder Associates Ltd. (Golder) has conducted an audit of five designated High Consequence dams that are part of the existing South East Kelowna Irrigation District (SEKID) water permit. The purpose of the audit was to provide an assessment of the current dam conditions and associated appurtenances as well as review historical piezometric data and maintenance records. Based on these results, comments regarding potential dam deficiencies are provided herein as well as a prioritize list of short and long term remedial works together with additional monitoring, if required.

It should be noted that the scope of this report is limited to the geotechnical assessment and does not include any investigations, analytical testing or assessments of possible soil and groundwater contamination, biological considerations or sediment control measures. The audit is also not to be considered as a complete Dam Safety Review (DSR) as defined by the Canadian Dam Association’s safety guidelines.

This report should be read in conjunction with “Important Information and Limitations of This Report” which is appended following the text. The reader’s attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report. The Dam Safety Section of the British Columbia Water Management Branch is the regulatory authority (Dam Safety Officer) for dam safety and as such is designated as an authorized user of this report and may rely upon its content for review purposes.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>i</td>
</tr>
<tr>
<td>1.0 HIGH CONSEQUENCE DAMS</td>
<td>1</td>
</tr>
<tr>
<td>2.0 BACKGROUND</td>
<td>1</td>
</tr>
<tr>
<td>3.0 DAM INSPECTIONS</td>
<td>1</td>
</tr>
<tr>
<td>3.1 North Dam</td>
<td>2</td>
</tr>
<tr>
<td>3.2 East Dam</td>
<td>3</td>
</tr>
<tr>
<td>3.3 South Dam (including Spillway Structure)</td>
<td>3</td>
</tr>
<tr>
<td>3.4 Haynes Dam</td>
<td>4</td>
</tr>
<tr>
<td>3.5 Lynx Dam</td>
<td>4</td>
</tr>
<tr>
<td>4.0 REVIEW OF AVAILABLE INFORMATION</td>
<td>5</td>
</tr>
<tr>
<td>4.1 2003 Outlet Pipe Video (North Dam)</td>
<td>5</td>
</tr>
<tr>
<td>4.2 1988 Outlet Pipe Inspection</td>
<td>6</td>
</tr>
<tr>
<td>4.3 Sluice Gates</td>
<td>6</td>
</tr>
<tr>
<td>4.4 Chemical Testing</td>
<td>7</td>
</tr>
<tr>
<td>4.5 BCWIB North Dam and Outlet Pipe Drawings</td>
<td>7</td>
</tr>
<tr>
<td>4.6 Previous Dam Inspections</td>
<td>7</td>
</tr>
<tr>
<td>4.7 Piezometric Data</td>
<td>8</td>
</tr>
<tr>
<td>5.0 GEOTECHNICAL ASSESSMENT</td>
<td>8</td>
</tr>
<tr>
<td>5.1 North Dam</td>
<td>8</td>
</tr>
<tr>
<td>5.1.1 Dam</td>
<td>8</td>
</tr>
<tr>
<td>5.1.2 Outlet Pipe</td>
<td>9</td>
</tr>
<tr>
<td>5.1.3 Gate Chamber and Sluice Gates</td>
<td>10</td>
</tr>
<tr>
<td>5.1.4 Monitoring Piezometers</td>
<td>10</td>
</tr>
<tr>
<td>5.2 East Dam</td>
<td>11</td>
</tr>
<tr>
<td>5.3 South Dam with Spillway</td>
<td>12</td>
</tr>
<tr>
<td>5.3.1 Dam</td>
<td>12</td>
</tr>
<tr>
<td>5.3.2 Spillway</td>
<td>12</td>
</tr>
<tr>
<td>5.4 Haynes Dam</td>
<td>12</td>
</tr>
<tr>
<td>5.5 Lynx Dam</td>
<td>13</td>
</tr>
<tr>
<td>5.6 Reporting and Dam Inspections</td>
<td>13</td>
</tr>
<tr>
<td>6.0 LIST OF PRIORITIES</td>
<td>14</td>
</tr>
<tr>
<td>7.0 CLOSURE</td>
<td>15</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1  Video Remarks
Table 2  Summary of Dam Conditions
Table 3  Proposed Engineering Assessments and Remedial Works

LIST OF FIGURES

Figure 1  Key Plan
Figure 2  North Dam Photographs
Figure 3  East Dam Photographs
Figure 4  South Dam Photographs
Figure 5  Haynes Dam Photographs
Figure 6  Lynx Dam Photographs
Figure 7  Typical Section North Dam (Concrete Outlet Pipe)

LIST OF APPENDICES

Appendix 1  Piezometer Readings
1.0 HIGH CONSEQUENCE DAMS

The British Columbia Dam Safety Guidelines states that the consequence classification from the failure of a dam and its downstream impact is determined using the following criteria.

- Potential for loss of life,
- Economic and social loss, and
- Environmental and cultural losses.

It is our understanding that the Dam Safety Officer has classified the following SEKID earth filled dams as High Consequence Dams.

- North Dam
- East Dam
- South Dam (including spillway structure)
- Haynes Dam
- Lynx Dam

2.0 BACKGROUND

The series of existing earth-filled dams were constructed within the Hydraulic Lake chain for domestic and irrigation requirements within SEKID distribution area. These dams were generally constructed in the late 1970’s and raised in 1995 to increase the available storage capacity within the McCulloch Reservoir by an additional 0.3 m. It is our understanding that the North Dam and upstream portion of the outlet pipe were originally constructed in the early 1900’s.

3.0 DAM INSPECTIONS

An inspection was conducted at each of the above dams on June 25, 2004 with Dave Metcalf of SEKID. At the time of the inspection, the McCulloch Lake reservoir was near its full capacity at an elevation of 1259.77 m (spillway crest elevation = 1259.86 m). Reference to the original design drawings prepared by the British Columbia Water Investigations Branch (BCWIB) is also provided for discussion purposes. The reference drawings were scanned and converted to PDF documents and are available for computer access using the attached CD-ROM.
The following conditions were inspected as part of the audit.

- Evidence of previous overtopping and/or loss of freeboard caused by restrictions within the spillway structure and/or wave erosion due to storm events.
- Review of appurtenances including outlets pipes, erosion of channel side slopes, spillway and log booms.
- Examination of the upstream and downstream slopes for indication of sloughing and/or areas where excessive settlement has occurred.
- Identification of seepage and/or saturation along the downstream slope and abutments.
- Indications of recent maintenance such as removal of tree and shrub growth and placement of rip rap protection.

3.1 North Dam

The following provides a summary of our observations at the North Dam:

- The dam was clear of tree and shrub growth.
- Recent rodent activity was noted along the downstream face of the dam, especially downslope from the gatehouse and adjacent to the left abutment.
- Seepage and a wet area were noted along the downstream toe of the dam for a distance of about 30 m between piezometer locations P1 and P3 with evidence of shallow sloughing above the seepage area (see Figure 2 photographs and BCWIB Dwg. No 4567-73M for piezometer locations).
- Minor wave erosion noted immediately upstream of the gatehouse.
- Sluice gate opened with discharge rate at approximately 20,000 gpm.
- Unable to locate the original alignment markers along the dam axis.
- No field reference numbers noted on the piezometers relative to the piezometer location plan.
- Concrete outlet structure did not show evidence of surface concrete deterioration such as cracking, spalling and/or scaling.
- Existing wire fence along the downstream toe of the embankment was in disrepair.
- Evidence of surface runoff being directed along the downstream toe of the dam off the existing access road resulting in surface ponding at the toe of the dam.
3.2 East Dam

The following provides a summary of our observations at the East Dam:

- The reservoir water level was measured at about 1.7 m below the crest of the dam.
- Significant shrub growth was noted along the downstream face (see photos 842 and 846 on Figure 3).
- Rip rap along the upstream face was not consistent in coverage.
- Wet area observed along the right abutment (approx. Sta. 7+50 on BCWIB Dwg. No. 4567-73D-1) at a distance of 2.2 m below the crest of the dam (see photo 847 on Figure 3). Shallow hand excavated test pit showed evidence of slight groundwater seepage within native deposits that consist of compact gravelly fine sand and silt.
- Minor erosion channels on the downstream face resulting from surface runoff off the dam crest.
- Rodent activity noted within the downstream face of the dam.

3.3 South Dam (including Spillway Structure)

The following provides a summary of our observations at the South Dam:

- The reservoir level was about 9 cm below the spillway crest elevation of 1259.86 m.
- No indication of sloughing was noted across the upstream and downstream faces.
- Rodent activity was noted within the downstream portion of the dam.
- The steel cable fastening the log boom to the left side of the spillway structure exhibited significant oxidation.
- Hairline cracking of the concrete face was noted along the downstream side of the spillway structure.
- Seepage was noted at the toe of spillway structure along the concrete apron (see photo 850 on Figure 4) and through a piece of wood (2”x4” butt end) embedded in the spillway structure (see photo 852 on Figure 4) and at a distance of 4.3 m left of the wood along a vertical control joint. Wicking was also noted through the wood with severe spalling of the adjacent concrete face. Observations indicated that the concrete facing appeared to consist of a relatively thin concrete veneer and/or parging.
• Tree and brush growth present within the spillway channel (see photos 850 and 851 on Figure 4).
• Sapling and brush growth present along the upper portion of the upstream face of the dam.

3.4 Haynes Dam

The following provides a summary of our observations at Haynes Dam:

• The reservoir water level was measured at about 1.5 m below the average crest height of the dam.
• The dam appeared to be founded on granular deposits consisting of sand and gravel with cobbles and boulders.
• No angular riprap was noted along the upstream face (see photos 856 and 858 on Figure 5).
• No sloughing was noted along the upstream and downstream faces (see photo 857 on Figure 5), except near the water line where over-steepened slopes were noted. The over-steepened slopes were generally located between Sta. 1+00 and 3+00 feet (see Dwg. No. 4567-73E1).
• Rodent activity was not evident within any portion of the dam.
• A bedrock outcrop was noted within the downstream face of the dam opposite Sta. 3+00.
• Ponded water was noted near the downstream toe of the dam in a localized depression. Minor surface flows were noted flowing into the depression.
• Sapling and brush growth present along the upstream face of the dam with clustered growth at several locations along the downstream face.

3.5 Lynx Dam

It is understood that the dam was previously referenced as the “West Saddle Dam” on the BCWIB drawings. Observations indicate that recent earthworks and riprap placement has been carried out throughout the length of the dam and that this work was conducted in September, 2002.
The following provides a summary of our observations of the dam conditions.

- The reservoir water level was measured at about 1.6 m below the average crest height of the dam.
- Ponded water (see photo 869 on Figure 6) was noted immediately downslope of the dam between Sta. 2+40 and 3+50 feet (see Dwg. No. 4567-73G-1). The ponded water level was measured at about 2.1 m below the average crest height or about 0.5 m below the reservoir water level.
- Groundwater seepage and slight ponding was also observed along the downstream toe of the dam between Sta. 1+00 and 2+40 (see photo 871 on Figure 6).
- The re-constructed dam crest width ranged between 7 to 8 m and generally consisted of silty sand and gravel.
- The upstream face was overlain by about a 0.45 m thick layer of angular shot rock that ranged up to 0.4 m in diameter (see photo 872 on Figure 6).
- No sloughing was noted along the upstream and downstream faces.
- Rodent activity was evident along the dam.
- Sapling and brush growth was recently removed. A pile of wood debris was noted along the downstream face of the embankment (see photo 869 on Figure 6).

4.0 REVIEW OF AVAILABLE INFORMATION

As part of the audit, a review of available dam surveillance and piezometric data between 1998 and 2004 was carried out together with some incomplete piezometer records taken during 1979 and 1993. A video of the existing outlet pipe at the North Dam was also provided for review together with photographs and report from a November 1988 inspection conducted by the Dam Inspector. Comments regarding these reviews are summarized in Section 5.0.

A sample from the McCulloch Reservoir was collected by a SEKID staff member on July 27, 2004 and delivered to Caro Environmental Services for determination of the pH level and sulphate concentration.

4.1 2003 Outlet Pipe Video (North Dam)

It is understood that SEKID undertook a video inspection of the existing outlet pipe between the discharge end and the gate chamber for a distance of about 65 m on May 14, 2003. The analog video was converted to digital video (wmv file format) and can be viewed on a WINDOWS based computer. The digital movie file is also included on the CD-ROM for future reference purposes.
It is understood that general comments during the video inspection were provided by a SEKID staff member. These comments are summarized in Table 1. The distances shown are relative to the discharge end of the pipe that was referenced to the video clip time. Figure 7 shows selected photograph clips and comments taken from the video along the pipe profile.

### 4.2 1988 Outlet Pipe Inspection

Review of the November 25, 1988 inspection conducted by the Provincial Dam Inspection Engineers indicates that the outlet pipe was considered to be in “reasonably good condition” with “no serious leakage, erosion, or misalignment of the precast sections”. Several minor leaks were noted along the top of the pipe.

An inspection of the gate chamber since its 1973 construction indicated that the steel liner used as part of the formwork was nearly all removed from turbulent gate flow, erosion of concrete along a horizontal construction joint to a depth of 1 to 3 cm, and gate leakage of about 50 IGPM through the right gate (looking downstream). The left gate (looking downstream) was noted as being well sealed and in good condition, but had not been used for a number of years.

It was recommended that the Operation and Maintenance Manual (OMM) be revised to include a schedule for regular use of both gates in order to determine their operational condition together with regular inspections of the outlet pipe and gate chamber. It was further recommended that the concrete construction joint also be repaired to prevent further deterioration of the concrete.

### 4.3 Sluice Gates

Discussions with Toby Pike (SEKID Manager) and Aaron Kunstar (SEKID Foreman), indicated that recent difficulties have been experienced with the opening and closing of the left sluice gate (looking downstream) using the automatic actuator. It is understood that the actuator stalled during operation. It is further understood that the gate can be closed by overriding the automatic actuator and possibly be opened using the manual gate wheel. In essence, the left sluice gate has not been operational using the automatic actuator since September 2004.

A recent underwater inspection was carried out to determine if the gates were subjected to interference from accumulation of debris. The diver was not able to identify any obvious obstructions that would cause interference. The diver also commented that no obvious structural deficiencies were noted regarding the stem assembly, gate chamber structure and sluice gate assembly. However, he did indicate that the trash rack was in poor condition.
4.4 Chemical Testing

The chemical testing on the McCulloch Reservoir water indicates it to be slightly acidic (pH value of 6.3) with a soluble sulphate content of less 1 mg/L. Typical pH levels in concrete are usually in the range of 11 to 13. Such pH levels can disintegrate concrete slowly which results into a porous concrete structure. This condition can promote corrosion of the embedded steel reinforcement.

4.5 BCWIB North Dam and Outlet Pipe Drawings

Review of the existing BCWIB drawings showing the outlet pipe was carried out to further define the general construction details. It is understood that the original outlet pipe was constructed in the early 1900’s. Details regarding its construction are unavailable.

BCWIB drawings 4734-C5G, C5J and C5L indicate that two large seepage collars were installed in 1951 along the outlet pipe upstream of the dam centre line. These drawings also show a number of smaller seepage collars evenly spaced along the outlet pipe.

During 1978, the dam improvements that were carried out consisted of the following:

- The dam was raised by 1.37 m to an elevation of 1260.81 m. The dam centre line was moved 4.57 m further downstream to allow for the construction of a 3 horizontal to 1 vertical downstream face.
- Extension of the 0.91 m diameter concrete pipe by about 11.6 m through the new fill section.
- Construction of new concrete outlet structure.
- Replacement of sluice gate and gate stem assembly works.
- Lining of pipe invert (30 cm width x 1.3 cm thick) using bonding coat application, cement mortar and coated with an epoxy grout finish.

4.6 Previous Dam Inspections

Available information from the SEKID dam inspections carried out between 1998 and 2002 were reviewed. Table 2 provides a summary of the dam conditions that were identified as requiring further work.
4.7 Piezometric Data

Piezometric records from seven piezometers located at the North Dam (see BCWIB Dwg. No. 4734-C5J) were reviewed. The records consisted of occasional monthly piezometer and reservoir staff depth readings for 1976, 1979, 1993, 1998 through 2000 and regular monthly readings since July 2000. Details regarding the piezometer installations were not available at the time of the review.

Piezometric depth readings were converted to geodetic elevations. Using the geodetic data, the phreatic surface was plotted relative to the dam crest and spillway elevations that were applicable for the corresponding recording period. The piezometric data is included with the attached CD-ROM (EXCEL spreadsheet file format). Various graphical summaries of the piezometer readings are provided in Appendix 1 for your reference.

The graphical summaries consist of historical and annual charts plotted on a monthly basis. The historical summary presents the monthly readings at each piezometer during the years 1979, 1993, 1998, 2001 through 2003. This summary shows the phreatic fluctuation and piezometer response relative to the change in reservoir water levels. The annual piezometer summary shows the monthly variation between each piezometer relative to the change in reservoir levels.

5.0 GEOTECHNICAL ASSESSMENT

Based on results of the inspections together with review of available information, the following summarizes our comments regarding the condition of the dams and deficiencies.

5.1 North Dam

5.1.1 Dam

In general, the inspections indicate this dam appears to be well maintained. However, the following conditions were noted that require attention.

- Rodent activity was noted along portions of the downstream face. It is recommended that measures be implemented to control the rodents.
• Evidence of seepage and sloughing along the downstream toe of the dam between piezometers P1 and P3 was noted. This condition should be monitored on a monthly basis to determine the lateral extent and seepage rate (if possible). Marker stakes should be placed as reference points that can be used to determine whether there has been any change in seepage conditions, especially when inspected by a different staff member. It is also recommended that consideration be given to re-grading along the toe of the dam to prevent ponding of water and to restrict runoff from flowing towards and alongside the toe of the dam.

• Minor sloughing and/or erosion of riprap cover immediately upstream from the gatehouse structure was noted. It is recommended that additional riprap be placed to minimize further erosion from wave action.

• Remove the brush in front of the gatehouse.

• Repair the existing fence along the downstream toe of the dam. Previous inspection reports indicate that the fence repair is an outstanding issue.

5.1.2 Outlet Pipe

Review of the pipe video and 1988 inspection photographs together with SEKID commentary indicates that the original section of pipe installed prior to the 1978 extension has experienced deterioration where it was recommended that a thin concrete mortar be applied along the pipe invert. The video also indicates that this mortar has almost completely spalled and/or scoured away from the invert resulting in a condition that is likely more severe than 1988 conditions. In addition, the video revealed a number of leaks and “blisters” along the pipe sidewall and crown which occur at a greater frequency relative to the 1988 inspection. The “blisters” appear to refer to be areas of efflorescence suggesting that hydroxides have leached from the concrete. Cracks were also noted at some locations where efflorescence was present.

The cause for cracking could not be readily determined from viewing the video. Considering that the reservoir water is slightly acidic, this would likely have some deteriorating effects on the concrete. The “mineral” build-up from leaching of cement compounds has also probably weakened the surface of the pipe, which then becomes subject to greater scaling and loss of pipe wall thickness. Measurement of the pipe diameter was never carried out at the time of the 2003 video. Such measurements would be useful to determine the magnitude of spalling and/or scaling that has occurred.
Based on the information provided, it is apparent that the outlet pipe has experienced further deterioration as compared to the 1988 inspection. Therefore, it is recommended that a detailed inspection by a qualified materials engineer be conducted to determine the pipe’s structural integrity which would include delam survey, corrosion testing, chemical analysis of concrete, rebar cover survey, etc…). Considering the age of the concrete pipe, it is recommended that only non-destructive testing methods be carried out to evaluate the condition of the concrete in order to provide remediation options and their associated costs.

5.1.3 Gate Chamber and Sluice Gates

Based on the available information, it is apparent that regularly scheduled maintenance and operational checks on both gates should be implemented according to the 1988 Dam Inspection Report recommendations and revised OMM. It is recommended that all documentation related to the sluice gates be assimilated and reviewed to determine what work has been carried out since the 1988 report.

In addition, it is further recommended that as part of the future outlet pipe inspection, that a detailed inspection of the sluice gate assembly be included to determine its operational and structural integrity, at which time the gate assembly should be closely examined. It is also suggested that prior to the gate assembly inspection, that design drawings and schematics of the gates (24” x 24” CANRON model R/6E) be provided to help determine deficiencies within the sluice gate assemblies.

5.1.4 Monitoring Piezometers

At the time of the inspection, it was noted that the piezometers were not field labeled. It was also noted that the plan reference numbers were not consistent with the recording numbers. As such, this has created confusion and inconsistencies in monitoring data, especially when different staff members are involved.

It is recommended that permanent field labels be installed on each piezometer that will correspond to the original piezometer location plan (see BCWIB Dwg. No. 4734-C5J for proper piezometer numbers).

The piezometric data for piezometer P1 indicates there is no response in the piezometer in relation to the fluctuating reservoir level. This condition extends back to 1979 and suggests that the piezometer is plugged as a result of corrosion. It is recommended that P1 be flushed using compressed air and/or pressured water. Flushing should be carried out starting from the tip of the piezometer and progress upwards. If the piezometer fails to respond, it is recommended that it be replaced.
The remaining piezometers appear to respond to the fluctuating reservoir levels and indicate expected phreatic conditions. At piezometer P2, the phreatic response is much quicker than at other piezometers. This would suggest that the embankment fill in the vicinity of the piezometer is more pervious and could be related to the sloughing and seepage conditions observed, as discussed in Section 3.1.

It should be noted that during the summer of 1993, the reservoir operated at its full capacity for a period of about 1 month longer than other years, which resulted in an increase in the overall phreatic surface by about 0.5 m relative to other years. The rise in the phreatic surface was typically about 0.5 m.

It is recommended that the piezometers be sounded to determine the sediment build-up within the pipe, flushed and sounded again to determine the tip depth. The amount of sediment build-up can indicate potential problems within the dam. In addition, the flushing will allow for better response of the phreatic surface.

5.2 East Dam

The observed dam conditions do not indicate any stability concerns. Dam maintenance should be continued on a regular basis which consists of brush clearing as well as placement of additional riprap within deficient areas.

As discussed in Section 3.2, slight seepage conditions were noted at a specific area along the right abutment. Measurements indicate that the seepage conditions probably exist only during periods when the reservoir is near its high water level. However, it is recommended that continued monitoring of this condition be conducted. A shallow piezometer could be installed at this location to facilitate monitoring. It is recommended that field stakes be installed to identify the outer most seepage limits to determine changes.

It is also recommended that the crest width be re-graded such that surface runoff is not allowed to be discharge in an uncontrolled manner across the downstream face, which results in the formation of erosion channels.

Measures to control the rodent should also be carried out.
5.3 South Dam with Spillway

5.3.1 Dam

No indication of sloughing was noted along the upstream and downstream faces of the dam. Rodent activity was noted within the downslope portion of the dam. As such, measures to control the rodents should be undertaken. Removal of tree and brush growth should continue on a regular basis.

5.3.2 Spillway

Heavy tree and brush growth was noted in the spillway channel. It is recommended that all tree and brush cover be completely removed.

Repair of the concrete facing should be considered as fine cracking was noted throughout the concrete parging that was carried out in 1995 for the raising of the structure. Surface remediation should consist of a durable; non-shrink modified structural mortar such as Master Builder’s Emaco S88 CI structural mortar or equivalent and applied according to the manufacturer’s preparation and application instructions.

In addition, it is recommended that the existing wood cutoff be removed from and concrete patched using hydraulic cement. Continued monitoring of the seepage along the concrete apron should be maintained to determine if conditions during high water levels indicate increased seepage.

The log boom appears to be in satisfactory conditions. However, it should be noted that the steel cable assembly located at the right abutment/spillway end shows significant corrosion. It is recommended that the cable be examined to determine the extent of the corrosion. It may be necessary to replace the cable and/or clean and paint with a rust-inhibitor epoxy primer.

5.4 Haynes Dam

Observations did not indicate any stability concerns. Dam maintenance should be continued on a regular basis which generally consists of brush clearing.

As discussed in Section 3.4, riprap protection does not exist along the upstream face of the dam. Observations indicate that section of slope exposed to wave action has become over-steepened. It is recommended that consideration be given to providing riprap in this area. Further assessment is required to determine the riprap size and thickness in order to provide adequate protection from wave action.
Based on the review of the SEKID dam inspection reports, it is apparent that surface water is allowed to pond along the toe of the downstream dam. It is suggested that consideration be provide in re-grading such that these low lying areas are ditched to allow drainage away from the dam.

5.5 Lynx Dam

As discussed in Section 3.5, significant remediation was conducted in September 2002 with the reconstruction of the dam, placement of riprap protection and clearing of trees and brush growth. However, the significant area of ponded water against the downstream toe of the dam should be closely monitored with staff readings taken on a monthly basis. The downstream staff readings should be surveyed such that it corresponds to the geodetic reservoir level.

During our inspection, ponded water was measured at 0.5 m below the reservoir water level. As such, it is recommended that consideration be given with installation of a monitoring piezometer to determine the phreatic condition through the dam embankment.

A review of the downstream topography should also be conducted to determine the feasibility for construction of a ditch to drain the ponded water. In addition, ditching should also be carried out between Sta. 1+00 and 2+40 to collect and direct the water away from the toe of the dam.

5.6 Reporting and Dam Inspections

It is our understanding that routine visual inspections are carried out on a monthly basis for all of the existing dam sites owned by SEKID, which includes High and Low Consequence Dams. The BC Dam Safety Guidelines suggests that weekly visual inspections be carried for High Consequence Dams and that a reduced schedule can be implemented considering access restraints because of adverse seasonal conditions. It is also recommended that piezometer readings be taken during the weekly visit.

Based on these minimum requirements, it is recommended that weekly inspections be considered on the North, East and South dam sites. Monthly inspections at the Haynes and Lynx dam sites can continue.

BC Dam Safety Guidelines also suggest that a Dam Safety Review (DSR) be conducted every 7 years for High Consequence and every 10 years for Low Consequence dams. To our knowledge, no DSR has ever been carried out according to that criterion.
In addition to the above, it is recommended that for each dam inspection visit, digital photographs be taken from the same perspective to identify subtle changes that may be occurring. The perspective locations should be clearly marked such that consistency is maintained in the event that different staff is involved in the inspection process. The photographs should clearly show the right and left abutments, upstream and downstream faces.

In addition to digital photographs, records should be kept up to date using an archive system that allows for quick retrieval. Golder has included a version of a database software tool developed by BC Hydro to facilitate such an archive system that is specific to the five High Consequence Dam sites. Additional dam sites can also be incorporated into the software for data recording purposes. The software will allow the user to categorize and prioritize dam maintenance items to avoid potential problems.

SEKID inspectors should also become familiar with the BC Dam Safety Guidelines regarding inspection and maintenance requirements.

6.0 LIST OF PRIORITIES

Based on the results of the dam audit, it is our opinion that SEKID have generally been pro-active in the operational and maintenance of the dams by carrying out dam remediation on a regular basis, which generally consists of brush clearing, rodent control, removal of debris and riprap replacement.

However, the audit suggests that a detailed assessment of the appurtenances at the North and South dams should be carried out to determine the structural soundness of the concrete outlet pipe and effectiveness of the 1995 parging and seepage along the apron at the spillway, respectively.

Table 3 presents a summary list of proposed engineering assessments and remedial works that should be carried out based on priority and scheduling criteria. This list does not include tasks that form part of the regular operational and maintenance requirements.
7.0 CLOSURE

We trust the foregoing provides you with the information that you require at this time. Should you require additional information or have any questions, please do not hesitate to contact the undersigned at your earliest convenience.

Yours very truly,

GOLDER ASSOCIATES LTD.

R. Therrien, AScT
Senior Engineering Technologist

G. Infada, P.Eng.
Associate, Geotechnical Engineer

Encl.
RT/Ge/ac

Golder Associates
IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing in British Columbia, subject to the time limits and physical constraints applicable to this report. No other warranty, express or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder’s express written consent. Golder will consent to any reasonable request by the Client to approve the use of this report by other parties as Approved Users. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, and only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder’s report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use by any party of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs, techniques and equipment choice, scheduling and sequence of operations would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work.
IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT (CONTINUED)

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect certain conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between sampling points may differ from those that actually exist.

Groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their measurement. Groundwater conditions may vary between reported locations and can be affected by annual, seasonal and special meteorological conditions or tidal fluctuations. Groundwater conditions may also be altered by construction activity on or in the vicinity of the project site.

Sample Disposal: All contaminated samples and materials shall remain the property and responsibility of the Client for proper disposal. Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client’s expense.

Follow-Up and Construction Services: All details of the design and proposed construction may not be known at the time of submission of Golder’s report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder’s report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder’s report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder’s report. Adequate field review, observation and testing during construction is necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities.
<table>
<thead>
<tr>
<th>VIDEO REMARKS (SEKID COMMENTS)</th>
<th>Distance</th>
<th>Video Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ft.)</td>
<td>(m)</td>
</tr>
<tr>
<td>1. Joint leaking.</td>
<td>55</td>
<td>16.8</td>
</tr>
<tr>
<td>2. Blister on left sidewall.</td>
<td>75</td>
<td>22.9</td>
</tr>
<tr>
<td>3. Debris on floor (appears to be mineral build-up).</td>
<td>78</td>
<td>23.8</td>
</tr>
<tr>
<td>4. Blister on right side.</td>
<td>84</td>
<td>25.6</td>
</tr>
<tr>
<td>5. Roof soft, drips.</td>
<td>86</td>
<td>26.2</td>
</tr>
<tr>
<td>6. Mineral build-up.</td>
<td>95</td>
<td>29.0</td>
</tr>
<tr>
<td>7. Right side.</td>
<td>130</td>
<td>39.6</td>
</tr>
<tr>
<td>8. Blisters, water dripping.</td>
<td>154</td>
<td>46.9</td>
</tr>
<tr>
<td>9. Loose debris.</td>
<td>156</td>
<td>47.5</td>
</tr>
<tr>
<td>10. Half way up the pipe, left side, roof patchy.</td>
<td>187</td>
<td>57.0</td>
</tr>
<tr>
<td>11. Right side, half way runs down, mineral build-up on bottom (hard).</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12. Gate structure/chamber.</td>
<td>210</td>
<td>64.0</td>
</tr>
</tbody>
</table>

September 2004
04-1440-134
<table>
<thead>
<tr>
<th>Date</th>
<th>Required Remediation</th>
<th>Dam Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/24/1998</td>
<td>Fence repair required.</td>
<td>North</td>
</tr>
<tr>
<td>9/18/1998</td>
<td>Fence repair required.</td>
<td>☑</td>
</tr>
<tr>
<td>6/7/1999</td>
<td>Fence repair required.</td>
<td>☑</td>
</tr>
<tr>
<td>4/24/2000</td>
<td>Fence repair required.</td>
<td>☑</td>
</tr>
<tr>
<td>7/26/2000</td>
<td>Brush removal (u/s and d/s). Wood debris on u/s face. Fence repair required.</td>
<td>☑</td>
</tr>
<tr>
<td>12/8/2000</td>
<td>Minor tree growth.</td>
<td>☑</td>
</tr>
<tr>
<td>1/7/2001</td>
<td>No comments</td>
<td>n/a</td>
</tr>
<tr>
<td>5/1/2001</td>
<td>Brush removal (u/s and d/s).</td>
<td>☑</td>
</tr>
<tr>
<td>Date</td>
<td>Condition Details</td>
<td>u/s</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>10/3/2001</td>
<td>Brush removal (u/s and d/s).</td>
<td>✓</td>
</tr>
<tr>
<td>11/13/2001</td>
<td>Water ponding/seepage at d/s toe.</td>
<td></td>
</tr>
</tbody>
</table>

Notes: n/a - no comments available. 
nv - no dam site inspection. 
d/s - downstream embankment face. 
u/s - upstream embankment face.
## TABLE 3
PROPOSED ENGINEERING ASSESSMENTS AND REMEDIAL WORKS

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Schedule</th>
<th>Priority Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Dam, outlet pipe and sluice gate assembly assessment.</td>
<td>Immediately.</td>
<td>High</td>
</tr>
<tr>
<td>Dam Safety Review including determination of the Probable Maximum Flood (PMF) to</td>
<td>Immediately.</td>
<td>High</td>
</tr>
<tr>
<td>determine if the spillway and drainage channel are capable to handle that event.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North, Dam, provide permanent labels identifying each piezometer.</td>
<td>Before end of current year.</td>
<td>Medium</td>
</tr>
<tr>
<td>North Dam, flush and/or replace piezometer P1.</td>
<td>Before end of current year.</td>
<td>Medium</td>
</tr>
<tr>
<td>North Dam, sound each piezometer and flush to maintain effectiveness. Replace</td>
<td>Before end of current year.</td>
<td>Medium</td>
</tr>
<tr>
<td>piezometers if required.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Dam, repair log boom cable.</td>
<td>Before next spring freshet.</td>
<td>Medium</td>
</tr>
<tr>
<td>South Dam, concrete parging assessment and removal of wood butt-end and determine</td>
<td>Within next 2 years to minimize</td>
<td>Medium</td>
</tr>
<tr>
<td>the cause for the seepage along the concrete apron.</td>
<td>further deterioration of existing</td>
<td></td>
</tr>
<tr>
<td>Haynes Dam, placement of riprap protection.</td>
<td>Within next 2 years to reduce the</td>
<td>Medium</td>
</tr>
<tr>
<td>potential for continuing over-steepening of the upstream embankment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lynx Dam, improve drainage of ponded water along toe of embankment.</td>
<td>Within next 2 years.</td>
<td>Medium</td>
</tr>
<tr>
<td>North Dam, locate original dam alignment markers.</td>
<td>Within the next few years.</td>
<td>Low</td>
</tr>
</tbody>
</table>

September 2004
04-1440-134
Photo 829 - Seepage area downslope along toe of embankment between piezometer P2 and P3. Note the moss cover indicating predominant wet conditions.

Photo 830 - Standing at upper limits of shallow embankment slough located between piezometer P2 and P3.

Photo 840 - Looking east towards outlet pipe at seepage and wet area along downgradient toe of embankment between piezometer P2 and P3.

North Dam Photographs

FIGURE 2
Photo 842 - Standing near right abutment and looking north along dam axis.

Photo 847 - Looking downgradient along right abutment at seepage area noted along toe of embankment. Note the shrub growth relative to the remaining areas of the embankment.

Photo 846 - Looking north along mid slope of embankment at typical embankment conditions. Note the shrub growth along crest of the embankment.

East Dam Photographs

FIGURE 3
Photo 850 - Standing at right embankment near end of concrete spillway. Note the water on the concrete apron where seepage is flowing between the spillway wall and concrete apron.

Photo 852 - Looking at spalled concrete area where wood is embedded into the spillway wall. Water is wicking through the wood. Note the cracking of the recently parged concrete face.

Photo 851 - Looking southwest along the spillway channel. Note the tree growth within the channel.
Photo 856 - Standing near left abutment and looking north along dam axis and upstream face. Note the lack of riprap cover protection along the upstream face of the embankment together with shrub growth.

Photo 857 - Standing near left abutment and looking north along the downstream face.

Photo 858 - Looking at embankment erosion from wave action from lack of riprap cover.

Haynes Dam Photographs

FIGURE 5
Photo 872 - Standing near left abutment and looking west along recently ripraped upstream face.

Photo 869 - Looking west, northwest along downstream embankment at pile of wood debris. Note standing water along toe of embankment. Pond water level measured at 0.5 m below the reservoir water level.

Photo 871 - Standing at about Station 2+00 and looking east at seepage and wet area along toe of embankment within a low lying area with lush growth.

Lynx Dam Photographs

FIGURE 6
NOTES
1) 38" dia x 35" diameter concrete pipe installed in 1978 as part of the dam improvement work.
2) Original concrete pipe laid using concrete mortar and for 2" wall thickness. (see NDHEC Doc. No. 4734-01c for lining details).
3) Comments regarding pipe video provided by SDMO.

REFERENCES
APPENDIX 1

PIEZOMETER READINGS
Historical Summary
<table>
<thead>
<tr>
<th>Month</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-Jan</td>
<td>1251</td>
</tr>
<tr>
<td>28-Jan</td>
<td>1252</td>
</tr>
<tr>
<td>25-Feb</td>
<td>1253</td>
</tr>
<tr>
<td>24-Mar</td>
<td>1254</td>
</tr>
<tr>
<td>21-Apr</td>
<td>1255</td>
</tr>
<tr>
<td>19-May</td>
<td>1256</td>
</tr>
<tr>
<td>16-Jun</td>
<td>1257</td>
</tr>
<tr>
<td>14-Jul</td>
<td>1258</td>
</tr>
<tr>
<td>11-Aug</td>
<td>1259</td>
</tr>
<tr>
<td>8-Sep</td>
<td>1260</td>
</tr>
<tr>
<td>6-Oct</td>
<td>1261</td>
</tr>
<tr>
<td>3-Nov</td>
<td>1260</td>
</tr>
<tr>
<td>1-Dec</td>
<td>1259</td>
</tr>
<tr>
<td>29-Dec</td>
<td>1258</td>
</tr>
</tbody>
</table>

Piezometer Readings at P5
McCulloch Lake - North Dam

---

- **Elevation (m)**
  - Spillway (1995): 1261
  - Crest (1995): 1258
  - Reservoir (1979): 1257
  - Reservoir (1993): 1256
  - Reservoir (1998): 1255
  - Reservoir (2001): 1254
  - Reservoir (2002): 1253
  - Reservoir (2003): 1252
Annual Piezometer Summary
2004 Piezometer Readings
McCulloch Lake - North Dam

<table>
<thead>
<tr>
<th>Month</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-Jan</td>
<td>1251</td>
</tr>
<tr>
<td>28-Jan</td>
<td>1252</td>
</tr>
<tr>
<td>25-Feb</td>
<td>1253</td>
</tr>
<tr>
<td>24-Mar</td>
<td>1254</td>
</tr>
<tr>
<td>21-Apr</td>
<td>1255</td>
</tr>
<tr>
<td>19-May</td>
<td>1256</td>
</tr>
<tr>
<td>16-Jun</td>
<td>1257</td>
</tr>
<tr>
<td>14-Jul</td>
<td>1258</td>
</tr>
<tr>
<td>11-Aug</td>
<td>1259</td>
</tr>
<tr>
<td>8-Sep</td>
<td>1260</td>
</tr>
<tr>
<td>6-Oct</td>
<td>1261</td>
</tr>
<tr>
<td>3-Nov</td>
<td></td>
</tr>
<tr>
<td>1-Dec</td>
<td></td>
</tr>
<tr>
<td>29-Dec</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Spillway (1995)
- Crest (1995)
- P1 (d/s)
- P2 (d/s)
- P3 (d/s)
- P4 (d/s)
- P5 (d/s)
- P7 (d/s)
- P8 (u/s)
- Reservoir