990 Campbell Street,
Nanaimo
British Columbia
V9R 3H6

6th May 2013

Mayor & Council.
City of Nanaimo

Ladies & Gentlemen,

I ask that you peruse the attached report and apply the contents to your deliberations on the future of the Colliery Dams.

Please give consideration to ordering a second look at the actual population contained within the Chase River flood inundation boundary, and a request for a further, much more detailed analysis of the potential fatalities, with a view to recalculating the dam failure consequence classification, particularly now that an effective warning and evacuation plan is in place.

Given the new standards, it is only fair that other residents threatened by dam failure elsewhere in and near the city should have the same level of safety. To this end, I have included population studies of an inundation boundary below Westwood Lake Dam. You will note that they are at least comparable with the Chase River flood population.

Both the Millstone River and the Cat Stream should be modelled with two-dimensional computer modeling to give a precise inundation result that accurately reflects the potential fatalities. While I very much like Westwood Lake, I might not be so enamoured if I lived beneath it.

All the dams should be studied in the interests of safety, including all the dams that could potentially breach into the Nanaimo River, again with two-dimensional tools. This is an ideal opportunity since dam safety reviews are about to begin on all City dams, and the scope could be extended.

Thank you for your consideration.

Yours truly,

Lawrence Rieper

IS NANAIMO SAFE ?

Questions about:
Dam Breach Consequence Classification, Inundation Studies
&
Emergency Preparedness

By Lawrence Rieper

Presented to Mayor & Council, City of Nanaimo

May 6th 2013

1 – SUMMARY

The premise is to question the validity of the population numbers for the Colliery dams flood inundation study that were provided by the City. Using the author's own research and information taken from the study, he proposes to show that those figures are considerably inflated. This in turn will affect the population at risk, and may also alter the number of potential fatalities, which in turn could reduce the dam failure consequence classification. In doing so, the potential cost of fixing the dams would be lowered, saving the tax payer's money and making more people happy. He proposes that these figures should be scrutinized and if proven right, they should be re-entered into the process of assessing fatalities. If the present emergency preparedness action plan is considered effective, then this too should make a difference to numbers of possible fatalities. If it doesn't make a difference, then he suggests that the warning and evacuation process must be a sham, and the people living in the inundation boundary beneath the dam are in considerable danger. He suggests that you cannot have it both ways.

The two Colliery dams have been decried as being a hundred years old and at the end of their service life, as well as posing an unacceptable risk to the community living downstream. But there are other dams that flow into the Chase River that are as old as the Colliery dams, for which concern has also been voiced in the past.

Westwood Lake Dam has a capacity many times greater than the Colliery dams. It is also slightly older, yet has a much lower dam failure consequence classification. The remedial work performed at Westwood in 2008 is now disregarded as an option for the Colliery dams yet Westwood Dam would still fail in an earthquake and flood downstream into the Millstone River and Cat Stream. From his research, the number of residents beneath Westwood could

actually match or exceed those under Colliery dams. We need to re-assess the risk to those people.

Likewise, the Jump Creek, South Fork and Fourth Lake dams hold an immense volume of water compared with the Colliery Dams and also have a lower failure consequence classification. They didn't avoid problems either. The Nanaimo River and Cedar populations have grown in the past quarter century. Their residents are entitled to know their risk too. New studies should be undertaken to provide answers.

CONTENTS

2 – INTRODUCTION

The question posed is in two parts. It will consider the available facts and figures and supporting documents, and make observations from the author's own investigation.

The first question asks if the information presented to Council on October 29th 2012 was true in all respects. Did Staff interpret and supply the best data in a balanced form that included all options? Was their guidance impartial? Are their assumptions still valid? How safe are the Colliery Dams now?

The second part arises from recent revelations about these dams. Are the other dams in the City, particularly those that would breach into Chase River, Millstone River and Nanaimo River as safe as has been assumed? Are new studies needed to meet new standards?

3 – MIDDLE & LOWER COLLIERY DAMS

The chase River watershed covers 20 square kilometers.

Middle Chase/Colliery Dam was built in 1910 with an earthfill concrete wall. Its height is 12.5 metres and width is 50 metres. It holds 93,000 cubic metres. The last safety review was done in 2003 and flood inundation assessment in July 2012. Its current failure consequence classification is "Extreme".

Lower Chase/Colliery Dam was built in 1910 with an earthfill concrete wall. Its height is 23.3 metres and width is 77 metres. The last safety review was done in 2003 and flood inundation assessment in July 2012. Its current failure consequence classification is "Extreme".

There are four Chase river Dams: Reservoir #1 and #2 (Upper Colliery Dam) and the two Colliery Dams (Middle and Lower),

as well as Harewood Dam that feeds into the Chase River just below Lower Colliery Dam. All five were built just over 100 years ago.

We are primarily concerned with the Middle and Lower Colliery Dams. Although inspected quite regularly (costing about $250,000 annually), no remedial work has been attempted on these two dams for over thirty years. This despite expensive and extensive engineering studies over the past decade that urged additional remediation. In 2002, water Management Consultants (WMC) Inc, produced the "Chase River Dams Incremental Damage Assessment", a study that modeled breaches in all four Chase River dams. Water Management Consultants also produced the "Middle and Lower Chase River Dams Spillway Hydrology Study in 2002. Their primary recommendation was an emergency spillway bypassing the Lower Dam (estimated to cost $1-million). In 2003, the Dam Safety Review conducted by Golder Associates raised concerns for dam safety, and recommended a seismic hazard assessment on the two dams. Five years later, in December 2008, the City of Nanaimo (CON) put out a request for proposals (RFP). EBA Engineering Consultants Ltd. was authorized to start work on February 24th 2009. They delivered "Seismic Hazard Assessment Middle and Lower Chase Dams" to Staff on 30th April 2010. An article in the Daily News dated May 15th 2010 discussed some of the findings of that study. In essence, the two dams wouldn't withstand a major earthquake, The options were to remove the structures (about $0.5-million & 1.5-million), reinforce them (about $0.5-million & $3-million) or replace them ($10-million). The seismic study also recommended a flood inundation study as well as interim Emergency Response Planning for evacuation. According to Bill Sims, Manager of Water Resources and Tom Hickey, General Manager of community Services, Staff did a seminar session of risks advising Council in October 2010. However, according to one former Councilor, it isn't clear that this briefing actually took place. The public didn't hear anything else

about these now potentially dangerous dams for more than two years.

We don't know how well informed previous Council members were, but we certainly lost the opportunity to discuss the dams and get a much cheaper fix. To the layman, this smacks of negligence. You will probably agree that first the conference centre and then the new city hall annex took a huge amount of City resources.

Chase River Dams Breach Flood Inundation Study

In the meantime, it seems that a RFQ was placed for "Engineering Consultant Services Chase River Dams Hydraulic Analysis and Improvements" on 1st June 2010 for a contract starting 15th September 2010. Short-listed were AE, EBA and KCB. The contract was awarded on 10th August 2010. The study by Associated Engineering Consultants Ltd. (AE), includes discussion on the Upper Chase River Dam dated March 8th 2011, and all their flood scenarios are dated June 22nd 2012. They signed off on "Chase River Dam Breach Flood Inundation Study" September 12th 2012.

EBA's seismic study took slightly over a year. AE's inundation study appears to have taken twice as long. It seems to have been Delivered in September 2012, but in a letter dated October 17th 2012, Scott Morgan, Section Head of bc Dam Safety Branch thanks Bill Sims, for invitations to a Dam Safety table Top Exercise on September 20th and 21st and for a copy of "Chase River Dams Breach Flood Inundation Study" dated July 2012. Does this mean there was a version released earlier than September, giving Staff not one month but three to consider the ramifications before addressing Council?

Associated Engineering is no stranger to Nanaimo. They provided

off-site works for the Port of Nanaimo Centre. In 2007 they developed the CON Water Supply Strategic Plan and currently are working on the new reservoir and the new water treatment plant.

This report was a game changer. In June 2010, the 80-year old Testalinden Lake Dam in the Interior burst and mud destroyed five homes. Subsequently staff from the BC Ministry of Environment began checking all dams in the province. New legislation was enacted in November 2011 and BC Dam Safety Regulations were amended to include a 5-tier Dam Failure Consequence Classification. What had been "High" or "High-Low" (less than 10 might die) for the two Colliery Dams was now "Extreme" (more than 100 people may die), the highest level. Whereas in 2003, they had to meet a design event of 1:3,000 years, the bar had been raised and any modification would have to meet a much higher design event of 1:10,000 years.

The study concluded that a dam breach flood inundation could cause between 80 (daytime) and 150 (nighttime) fatalities. No methodology was included as to how these figures were achieved. Details of casualties in the three reaches were: upstream (daytime) 20 and (nighttime) 30-40; Park Avenue area (daytime) 35-40 and (nighttime) 45-60; Elsewhere in the floodplain (unspecified) 40-50. Totals: daytime 95–100 and nighttime 105–150.

On reading the 2010 and 2012 studies, the most obvious differences are the detail in the former and its lack in the latter. This got me wondering about the population numbers used to justify the fatalities. The report states, "We have estimated the population within the flood zone based on the 2011 census data for the area by using the average population per housing unit and the number of dwelling units. The spatial distribution of dwelling units was provided by the City" The following information was tabled:

Estimated Daytime Population (Total 1810)
Single Family Homes & Apartment Buildings = 1.2 per house/unit;
John Barsby High School = 650;
Travelling Public = 100;
Day Care=23.
Estimated Nighttime Population (Total 1883)
Single Family Homes & Apartment Buildings = 2.2 per house/unit;
John Barsby High School = 5;
Travelling Public = 10.

If we subtract the day and night John Barsby and travelling public figures, as well as the daycare, from the totals we get 1037 and 1868 respectively. When divided by either 1.2 or 2.2 we get some odd results. Daytime houses/units are 864 but 849 at night. They should be the same. Mysteriously, 15 units disappear at night. Something is amiss.

The last City Directory was published in 2000. It records the number of housing units (mobile homes, apartments, houses) and their adult occupants where known. It reflects the situation 12 years ago and forms an information base which the author updated. He has walked and scrutinized the evacuation area and concluded which housing units are included. To simplify, the actual street and apartment numbers are not included in this report, but such details are available.

Following are the relevant streets and housing units thereon.

AEBIG ROAD. (all):	1
BROOKSIDE PLACE. (all):	8
BRUCE AVENUE. (Dundas to 8th):	35
Country Gardens (two 2-story apartment blocks +3 townhouses)	19
CARLISLE STREET. (all)	13
DEERING STREET. (Bruce to Park)	26
EIGHTH STEET. (east of Bruce)	6
GARDASAN WAY (all) – Duplexes?	22

GEORGIA AVENUE. (near 7th)	1
HEWGATE STREET. (all)	13
HOWARD AVENUE. (6th to Brookside)	6
HONEY DRIVE. Ed's Mobile Home Park)	49
JORDON AVENUE (all)	3
MURRAY STREET. (Bruce to Park)	22
NOVA STREET. (Georgia to Park)	37
OLD VICTORIA ROAD. (near end)	1
PARK AVENUE. (near 7th)	1
SEVENTH STREET. (Georgia to Park)	42
SIXTH STREET. (Georgia to Stirling)	9
Rivergate Townhouses	31
Willow Grove Estates (Apartments)	147
STIRLING AVENUE. (6th to 8th)	23
WINCHESTER AVENUE (Dundas to river)	25

Little has changed since 2000, but the following have been added:

EIGHTH ST.	2
GARDASAN WY.	4
MURRAY ST.	10
SEVENTH AVE.	1
STIRLING AVE.	1
Grand total	558

Bruce Avenue at 8th has five 4-plex residences being completed, a total of 20 units. However, they are not shown in AE's scenario maps and have been excluded from these totals too. There may be a slight discrepancy at some locations but the author believes that he has been generous in interpreting the boundaries.

558 times 1.2 or 2.2 yields a population of 669 (daytime) and 1227 (night). These are roughly two thirds of the AE study figures.

As a separate control sample, using some averaging for particular streets and sites, the 2000 directory figures were extrapolated into 725 adults. In 2000, city-wide, slightly over a quarter of the

population was 19 and under, which adds 175, and yields` a total of 900 for the evacuation area. Multiplying this amount by the ratio of increase in City population between the 2001 and 2011 census gives a local total of about 1033 persons in 2012. These differences in potential residents are enough to possibly change the number of fatalities to under 100 and hence the Consequence Classification.

Only three secondary suites appear in the 2000 Directory within the area. In 2008 there were estimated to be 1400 in the city. Dividing the 2011 population by the inundation area population gives a proportional number of 30 secondary suites in the area currently. Certainly not enough to explain the difference

In 2000, the three large 3-story apartments complex at Sixth and Bruce (Willow Grove Estates) was only about two-thirds occupied and average residency was one adult. For the purposes of this potential population at risk investigation all of the 147 suites have been included (each building has 49 units and each floor 18 or 19 units), whereas in reality, only the ground floor should be affected if the building isn't seriously damaged. One understands that the others may still need to be re-housed and might prefer evacuation to staying in a flood damaged area. This also goes for the two 2-story, 16-unit apartments (4 units per floor) at Sixth near Dundas (Country Gardens). Furthermore, only a third of the units at Ed's Mobile Home Park on Honey Drive are included in the flood scenarios, so 33 units could be removed. If (101+8+33=142) 142 units) are subtracted from 558 only 416 are left. This yields 499 (daytime) and 915 (nighttime) population. This is about half of AE's numbers (not including those travelling and on school grounds). With more effort, these numbers could probably be honed closer by comparing with the inundation maps but the point has been made.

Estimating fatalities from dam failure scenarios is anything but simple. The following selected comments are taken from (www.damsafety.org/media/Documents/Security/DamsSectorConsequenceEstimation-LossofLife.pdf) the US Department of Homeland Security document dated September 2011 "**Methods for Estimating Loss of Life Resulting from Dam Failure**" (94 pages).

It should be noted that the US classification for Small impounds (dams) is a height of 25 to 40 feet and to store 50 to less than 1000 acre-feet. Both Colliery Dams appear to fall within this category. "the majority of dam failure fatalities have been caused by dams having a size category of intermediate or large. …The failure of dams with a size category of small has caused comparatively few fatalities. …..loss of life resulting from small dams is most prevalent in close proximity to the dam.

Some methods of estimating loss of life:
DSO-99-06 Procedure
Flood Comparison Method
US Army Corps of Engineers/Utah State University LIFESim Models
BC Hydro Life Safety Model

Model Limitations and Uncertainty of Results
"Although it is the intent of each method to provide accurate and consistent estimates of loss of life, this goal is difficult to achieve. Inherent in any loss of life estimating methodology is uncertainty associated with natural variability; dependent on chance or luck, and arises because of natural and unpredictable variations in the performance of the dam under study. The other type of uncertainty is associated with the lack of, or error in, knowledge about the behavior of the system under study."

Bureau of Reclamation DSO-99-06 Procedure (*steps*)
1- Choose dam failure scenarios
2-Choose time categories
3-Evaluate areas flooded for each dam failure scenario
4-Estimate the number of people at risk for each failure scenario and time category
5-Estimate when dam failure warnings would be initiated
6-Estimate how often the warning time in downstream areas might fall in the none, some, and adequate categories
7-Evaluate how well the flood severity is understood
8-Estimate the proportion of the Population At Risk exposed to each of the three flood severity categories posed by the flood
9-Select appropriate fatality rate based on the flood characteristics in each reach (*there are three reaches, near, mid and far areas*)
10-Present life loss estimates
11-Evaluate how uncertainties in various parameters affect overall uncertainties in life loss estimates

"Loss of life relationships (fatality rates) are based on judgment. Fatality rates are more than 1,000 times greater for areas that receive no warning and high severity flooding than for areas that receive hours of accurate and forceful warnings and low severity (benign) floods."

The 2012 Inundation Study states:
"Seismic Event Induced dam Failure
A failure of the Lower dam during a 100-year flood or of the Middle and Lower dams during a seismic event presents the highest level of risk. Notably, these events result in damages that are similar to extreme events such as 1000-year floods or the PMF. Our assessment of potential casualties for the seismically induced dam failure assumes the following.
1-The Public is generally unaware that a significant earthquake would result in an immediate dam failure.

2-The public is generally unaware that seismically induced dam failure will result in damaging flows immediately downstream with no warning.
3-Residents will not receive notice of the dam failure or subsequent flooding, either by emergency personnel or nearby residents, until at least 30 minutes after the earthquake.
4-Ten percent of single family homes have an occupant who normally sleeps in the basement or ground floor (this refers to individuals trapped within basement areas).
We note that the number of casualties is difficult to estimate and there are many factors that will influence the fatality rate."
Here they inserted the "Estimate of Affected Population" chart that has already been tabled. These numbers seem to be their PAR.
"Many variables affect the population at risk including time of day and time of year (season). With respect to estimating the potential number of casualties, the single most important factor is the amount of warning time provided to the public prior to flooding, as well as the time required to evacuate the area. Providing sufficient warning in order to allow the population at risk to evacuate the area will dramatically reduce the number of potential casualties."
Various approaches are available for reducing the consequences of failure resulting from a dam breach. These include flood forecasting tools, educational programs for residents within the floodplain area, evacuation plans and evacuation notification system. These approaches would be expected to reduce the potential casualties for the events considered. However, these approaches would not reduce economic losses or significantly reduce the estimated casualties from a high probability seismically induced dam failure".

From the preceding paragraphs, one immediately wonders what the estimated loss of life might have been if the city had had an effective flood forecasting tool and a sound plan to provide emergency personnel with sufficient time for evacuation. One

wonders how aware Staff was beforehand too. Certainly, the residents can no longer be said to be unaware.

After Staff received the inundation study in July or September, a period of silence ensued. Then Staff presented their conclusion to Council who agreed to remove the dams. The Public were assured that, “The City has implemented an Emergency Action Plan that would see the Emergency Command Centre activated in the event of a possible breach. The City will order an evacuation of the downstream area should the dams appear to be in imminent danger of failure. The dams are stable in their current state; however a disturbance due to a significant earthquake or extreme rainfall event could negatively affect them.”

Why were these warning and evacuation safety measures not in place years ago? Why was there no remedial action on the dams?

Suddenly, as long as the dams were coming down in the following summer, everything was considered rosy throughout the winter, a time when heavy rainfall is expected. Wasn’t serious flooding possible? Surely, if there was a safety issue the dams should have been drained at once, but Staff declined the idea in December 2012.

Earthquakes are unpredictable. It would appear from the inundation study maps that the flood scenarios (100-year, 1000-year, PMF) are only really serious if combined with a dam failure. And, a dam failure, on its own, or a flood on its own is also largely accommodated within the river channels, with some additional damage nearby. It should be remembered that the dams survived the 7.3 earthquake centered at Forbidden Plateau in 1946

There are six scenarios modelled in the inundation study. For each there are two maps, for: property damage, flood warning and maximum flooding depth and extents.

dams whose inundation studies are almost a quarter of a century 1-1000-year flood with no breach;
2-1000-year flood with Lower & Middle dam breach;
3- 100% PMF with no dam breach;
4-100% PMF with Lower & Middle dam breach;
5-100-year flood with Lower dam breach;
6-Earthquake.

It would appear that #4 seems to be the worst situation and the only one with up to 50% damage to the high school. #2 seems like the runner up.

At the December 6th meeting, in answer to the question, "Is there an early warning system in place?" Bill Sims, Manager, CON Water Resources said, "We monitor for seepage 24/7". Susan Clift, Director of Engineering & Public Works said, "We need four hours to evacuate." With regard to an earthquake, it seems that residents have ten minutes after feeling the shaking to leave home and get to safety (higher ground).

On the maps, predictably, the deepest water was in or near the Chase River or within a bend of the river as well as the southern end of Stirling Avenue. Obviously, considerable damage to buildings is modeled, but I'm not sure how much of it directly relates to loss of life. The potential washout of the old Island Highway and the E & N Railway embankment and trestle was predicted in the 2010 study, so should not be unexpected.

The property damage maps have colours representing levels of building damage. Red indicates 75-100%, Orange indicates 50-75%, and Yellow represents 5-25%. However, there is a colour between yellow and orange which does not show up well on the maps. It represents 25-50%. People in a 100% destroyed building might survive yet others in a lesser damaged home may not.

From the Scenario 4, Property Damage map (which seems to be the greatest flood area and which corresponds closest to the evacuation map boundary). The total number of residences was counted, excluding a few buildings that clearly had commercial or utility functions. There were 255 houses and 15 mobile homes plus four multiple complexes (147+31=19+22=219) Total units = 489. This would yield a daytime population of 587, and a nighttime population of 1076. Since the latter is really the true population permanent figure, you will see that it compares favourably with the author's (projected and adjusted figure from 2000) control population of 1033, slightly more than half of the figure used in AE's study. Shouldn't this warrant a rethink of the potential fatalities. Coupled with an effective warning and evacuation plan, it should allow remediation of the dams to a lower consequence classification.

Inundation Analysis Emergency Preparedness Release Model, Chase River Dams, is a composite map prepared by CON Engineering Services/GIS, dated April 1st 2008 (hopefully, that's not a joke). It shows what one may suggest is the inundation boundary from the (2002) Water Management Consultants study of all four Chase River dams breaching. The maximum flooding covers less area than the maximum flooding modeled by Associated Engineering in 2012 for the two Colliery dams. It is the same scale as the Westwood Lake Dam emergency preparedness map, and covers about a third of the latter area.

Some quotes from Will Jolley, Senior Dam Safety Officer, 6th December 2012, "We didn't require that the dam be removed; we required that the risk be reduced. We wanted a plan and we wanted it soon. The risk has been known for some time and it now has been quantified properly. …. There is an early warning system in place right now with the automated seepage measuring and automated reservoir level."

4 – THE OTHER CHASE RIVER DAMS

Reservoir #1 has a concrete dam built about 1910. It was upgraded in 1996. Its height is 5.9 metres and width is 40 metres. It holds 64,000 cubic metres of water. Neither a safety review nor separate flood inundation study have ever been done. Its failure consequence classification is “High”. AE recommended verification of the ability of #1 Dam to resist overtopping floods. Has such a study been completed, or even considered?

Reservoir #2 (AKA Upper Colliery Dam) was also built in 1910. The dam has an ‘L’-shaped earthfill concrete wall and is 5.5 and 2.5 metres high with a width of 64 and 33 metres. It holds 60,000 cubic metres. From City records, it seems that it was included in the 2012 inundation study, and its last safety review was 2003. Its failure consequence classification is “Significant”. AE suggested in 2011 that the dam could be removed or spillway capacity provided for PMF and a 1000-year flood event, otherwise it could flood Nanaimo Lakes Road and destroy city water mains infrastructure. This is the only city dam that has ever actually broken – in 1921. The City questions and answers states, “the Upper Colliery Dam, is in a secure state and poses no risk to the public. … Also, Water Reservoir #1 has been seismically upgraded to current standards and poses no risk to the public”.

Harewood Dam is a concrete gravity dam built in 1911. Its height is 4 metres and width 34 metres. It holds 32,000 cubic metres. Its last dam safety review is marked N/A (Not Available or Not Applicable), and there is no flood inundation study. Its failure consequence classification is “Low”. EBA recommended a seismic assessment in 2010 for Harewood Dam and Reservoir #1. It does not appear to have happened.

If we are serious about safety in the flood plain, and the re-naturalization of the Chase River, all of these other dams must be

removed too. Then the only hazard would be the water mains and the new reservoir.

In the December 2002 Chase River Dams Phase 1 Incremental Damage Assessment for all dams failing on the four Chase River, the combined volume of water for the two Colliery Dams (Middle and Lower) is given as 266,000 cubic metres (93,000 + 173,000). To this is added #1 and #2 reservoirs and we get 266,000+60,000+64,000) 390,000 cubic metres. If Harewood Dam fails adding its contents to Chase River through Harewood Creek another 32,000 cubic metres gives a total of 422,000 cubic metres.

Interestingly, the City map "Chase River Emergency Preparedness inundation Analysis Return Model" shows all four dams flooding the Chase River. The flood area boundary is defined by Water Management Consultants and was presumably their 2002 study. One notices that flood area is significantly smaller and a slightly different shape than the current evacuation area (which reflects the worst case flooding envisaged by AE in 2012 for the two Colliery Dams) issued by the City at their open houses. It doesn't extend north of 6th Street and includes more of it, it doesn't extend as far south as 8th Street, and it cuts through 7th Street at Howard Avenue.

In the 2012 inundation study, the following dam failure details are given for combined volumes of water for the Middle and Lower dams in certain events: 100-year flood = 312,000 cubic metres; 1000-year flood = 363,000 cubic metres, and Probable Maximum flood = 443,000 cubic metres. Since this study reduced the estimated volume of the Middle and Lower Colliery Dams to 112,000 and 110,000 cubic metres respectively (total = 222,000 cubic metres), then this is an interesting comparison with the 2002 study. In these extreme events: 100-year = 90,000 cubic metres; 1000-year = 141,000 cubic metres; PMF = 221,000 cubic metres.

5 – WESTWOOD LAKE DAM, BUTTERTUBS MARSH & THE MILLSTONE RIVER

The catchment area of Westwood Lake is approximately 7 square kilometers. The Millstone River has a catchment area of 86.2 square kilometers. That's more than four times the catchment area of the Chase River. The total drainage area of the Millstone is 93.2 square kilometers.

The surface area of Westwood Lake is about 130 acres. The surface areas of each Colliery dam is about 8 acres or 16 acres combined. Together they represent about 1/8th of the area of Westwood Lake. The two Colliery dams have about 1/9th or 1/10th of the normal volume of Westwood Lake, although Westwood Lake could theoretically hold more than twenty times the capacity of the Colliery dams combined. All the lakes are roughly of similar general depth (up to around 10 metres), albeit right at the dam, Lower Colliery maybe a little deeper.

For a dam breach, with and without a Probable Maximum Flood in the maps from the 2004 "Westwood Lake Dam Inundation Study" by Water Management Consultants, the main flooded areas are about three or four times the area of the lake, suggesting at least 3 metres of coverage (although deeper in the river courses). With more than twice as much water than normal flooding into Westwood Dam in a serious flood, the depth above Buttertubs Marsh in a breach might be 6 metres.

The corresponding maps for the 2012 Chase River inundation study seem to show an area 12 to 15 times the combined area of the two dams, with a depth of 6 metres at the river channel, but much less, further away. This apparent inequity prompted the author to look at the Westwood Lake inundation study a bit more closely.

Inundation Analysis Emergency Preparedness Release Model, Westwood Lake Dam Rehab, is a composite map prepared by CON Engineering Services/GIS dated March 3rd 2008. It shows the inundation boundary from the (October 5th 2004) Water Management Consultants, Westwood Lake Inundation Study. It is the same scale as the Colliery Dams emergency preparedness map, and covers about three times the area of the Harewood inundation boundary. Again, this inequity between the Colliery dams and Westwood dam, which remember is more or less ten times bigger in both volume and area.

Westwood Dam is a zoned earthfill embankment and saddle dam, built in 1906. Its height is 12 and 2 metres and width is 100 and 130 metres. It normally holds 2.3 million cubic metres of water. However, the 2004 inundation study has a table showing at dam crest a volume of 4,688,000 cubic metres and up to 5,000,000 cubic metres at overflow. These two volumes should not be achieved as long as the spillway at the other end of the lake functions properly (unblocked by debris). Its last dam safety review was done in 2003 and a flood inundation study in October 2004. It has a failure consequence classification of “High Significant”; indicating less than 10 people may die.

Witchcraft Lake feeds into Westwood Lake. It has a timber crib earthfill dam built in 1910. Its height is 5 metres and width is 50 metres, and holds 31,000 cubic metres. There is no flood inundation study and the last safety review is marked ’N/A’.

Unlike the 2012 Chase river study, the Westwood Lake inundation study does not develop a population or PAR, nor was an estimation of casualties seen to support its present classification.

“The Westwood Lake Dam Safety Review (Golder, 2003) concluded that the dam is vulnerable to liquefaction related failure at much less than design earthquake level. Liquefaction could

result in sliding of the dam into the reservoir followed by overtopping of the dam and breaching." In 2003, Westwood Lake was the highest risk dam and a higher priority than Colliery Dams. The 2004 inundation study stated, "It was estimated that the maximum breach width would be 35.2 metres following a liquefaction failure".

To be fair to all, the same extreme events should be applied to the Westwood Dam as has been modeled for the Colliery Dams, with the same tools.

In 2008, the seismic upgrade to the existing Westwood Dam was to prevent a sudden discharge of water during or shortly after a 7.0 magnitude earthquake. The City budgeted $539,000 for a proposed new rock fill buttress downstream of the dam to add mass to it.

Hazards (from the CON website) quotes "For example, during the early summer of 2008, the city seismically stabilized Westwood Lake Dam – a 100 year old structure. Should a large magnitude earthquake occur, the dam is expected to slump, but the upgrade would slow the release of water to a manageable level."

The 2004 study suggests that a flood would be dissipated into Buttertubs Marsh and slowed due to the spillway (if it remains unblocked) and McNeil Creek. However, a dam breach would suggest a surge down Darrough Creek, possibly excavating the sides of the valley and damaging properties backing on to it. It would reach the Millstone River within minutes but apparently be slowed thereafter. Conversely, having washed away the fill and possibly Jingle Pot Road intersection, it might act like a bore, sweeping across Buttertubs Marsh and racing down the Millstone River. In spite of the flat area below (Buttertubs Marsh etc.) the water still wants to complete its decent to the sea along the Millstone River. Once the water got low enough to avoid the

spillway, it would all go through the dam break. Besides, whichever way it goes (and that includes flowing down Jingle Pot Road across the Parkway to Buttertubs Marsh), it still ends up in the Millstone River (unless it escapes into the Cat Steam). For a flood event, rain will be coming down locally and into the Millstone River from Brannen Lake and the rest of the watershed, so the flooding will continue.

The 2004 report includes inundation mapping for three scenarios: The 'worst case' scenario including a dam breach at the peak of the PMF; a dam breach occurring during normal flow conditions and the extent of the PMF without dam breach. In all these cases, the Parkway at the Millstone River seems to be flooded, giving a lie to using that route to evacuate Chase River residents to Beban Park. In fact, one could speculate that a surge might seriously damage the Highway. Bowen Road at the Quarterway Bridge and Buttertubs Drive would also be flooded and possibly damaged. Other partially flooded roads include: Adams Avenue, Bartlett Street, East Wellington Road, Fuller Street, Jingle Pot Road, Maxey Road and Westwood Road.

As had been done in Harewood previously, the author drove and walked the potential flood area for a breach of Westwood Dam. He noted the low areas along the Millstone River, by Maxey Road and through Buttertubs Marsh (now 100 acres, including the Conservation Area, West Marsh and Valley Oak Park). He also noticed places where the river was only about 2 metres below.

The following locations appear at risk:
ADAMS AVENUE – 15 homes + 4 houses
BARTLETT STREET – 24 homes
BIRD SANCTUARY DRIVE – 9 houses
BOWEN ROAD - 7 units (Bowen Terrace Apartments at ground level, part of a 3-story block)

BUTTERTUBS DRIVE – 10 units (Rebekah Villa) 32 units (Millstone Acres) 83 units (George Pearkes) + the community centre.
BUTTERTUBS PLACE – 32 units (Twelve Oaks)
CALEDONIA AVENUE – German Cultural Club
DURNIN ROAD – 8 houses
EAST WELLINGTON ROAD – 1 house
FULLER STREET – 20 homes (including 9 new ones constructed since 2009 on the flood plain)
JINGLE POT ROAD – 6 houses
MAXEY ROAD – 21 houses
RIVERSIDE DRIVE/GIRVIN AVENUE – 12 houses (in any normal winter, the river almost reaches the road)
VALLEY OAK ESTATES – 72 units (mobile homes)
WESTWOOD ROAD – 6 houses (near bridge)

This is a total of at least 363 dwelling units. At 1.2 or 2.2 persons per household (the formula used in the 2012 study) the daytime population is 434 and nighttime 796. If combined with the Cat Stream figures which follow (363 + 141 = 504 units), that becomes 605 (daytime) and 1109 (nighttime population. Without any damage criteria or a more detailed study it is impossible to work out possible fatalities. However, comparing with the previous adjusted figures for Chase River inundation there is a probability of more than 10.

There are also businesses: Pryde Vista Golf Course and club house, Quarterway Pub and liquor store, a fitness centre, farms with barns, crops, cattle, horses, equipment etc., representing many millions of dollars in damage.

It is apparent that different standards are being applied to the Westwood and Colliery dams. Partial fixes aren't allowed at the Colliery Dams, only definitive ones. Isn't it time that the residents who live in the shadow of Westwood Dam be offered the same

degree of safety as is being imposed on the Harewood residents and businesses. There should be a new inundation study for Westwood Dam using more advanced tools. Why should their lives remain at such high risk? Are they as much in the dark as the Harewood residents were?

6 – CAT STREAM

For almost the century that Jingle Pot Road has existed, in a major event, storm water from the flooded Millstone River has flowed across from the Buttertubs Marsh area, and into the Cat Stream.

The 2004 "Westwood Lake Dam Inundation Study", states, "For all scenarios there would be overtopping of Jingle Pot Road near Buttertubs Marsh and flow down the Cat Stream and into the Chase River. This overflow has not been incorporated in the inundation maps. Three inundation maps were prepared sowing the extent of inundation with a breach plus the PMF, the breach without the PMF and with the PMF and no breach. For all cases there would be spillover into the Cat Stream southeast of Buttertubs Marsh. The Cat Stream is a tributary of the Chase River. The peak outflow from a dam breach would reach the Millstone River within a few minutes. However, because of significant storage in Buttertubs Marsh, the peak water level in the Millstone at the Island Highway crossing, would be reached 100 minutes after the breach. It is recommended that mapping of the potential Westwood Lake Dam breach inundation in the Cat Stream and the Chase River be completed." Where is this recommendation nearly a decade later?

In considering how the Cat Stream might affect flooding in the Chase River, the author also looked at the potential flooding that might occur across the following through roads: Jingle Pot Road near Third Street, Wakesiah Avenue near Third Street, Howard Avenue near Gail Place, Third Street between Howard Avenue and Pine Street, Bruce Avenue near Foster Street, Chesterlea Avenue

near Pine Street, Pine Street near Durham Street, Albert Street at Pine Street, and Fifth Street between Park Avenue and Railway Avenue. Rescue efforts might be hampered.

He has also studied the properties adjacent to the Cat Stream that might be impacted by Westwood Lake Dam breach or major flooding of the Millstone River. He has identified many likely dwelling units (single family houses and apartment buildings):

BEACONSFIELD ROAD	7
BRUCE AVENUE	2
CHESTERLEA AVENUE	2
DURHAM STREET	3
FIFTH STREET	2
GAIL PLACE (including 24 townhouses)	34
HOWARD AVENUE (including 34 townhouses)	36
JOHNSTON PLACE	2
LAMBERT AVENUE (new)	1
O'BRIEN PLACE	4
PINE STREET	9
ROSAMOND STREET	2
TAYLOR PLACE	3
THIRD STREET (including a new duplex):	4
Pine Bluff apartments (two 3-story blocks)	72
WAKESIAH AVENUE:	
The Willows (condos.)	10
Chelsea Court (two 3-story apartment blocks)	20
TOTAL	213

There may be more or less units affected, depending on the volume of water and the velocity. These are rough calculations that can be added to my Westwood Dam inundation figures. Again, the apartment units can be adjusted to reflect flooding of the first floor only. That would mean (12x2=24) + (3x2=6) = 30. If one subtracts the remaining 72 then 141 dwelling units are left. If added to

Westwood Dam figures, a daytime population of 605 and nighttime one of 1109 is inferred.

7 – SOUTH FORK DAM, JUMP CREEK DAM, FOURTH LAKE DAM & NANAIMO RIVER

The watershed for Nanaimo's drinking water covers about 293 square kilometers. That is about 15 times bigger than Chase River watershed, and about 3 times the Millstone River watershed.

The author's attention was drawn to South Fork Dam when he realized that it held back almost the same amount of water as Westwood Lake Dam, yet is half the height and twice the width, and according to the 1990 Inundation Study would spew a massive amount of water into Nanaimo River and Cedar.

South Fork Dam was built in 1931. Its height is 25.6 metres, width 50.6 metres (about half the width of Westwood Dam) and holds 2-million cubic metres of water. This volume is slightly less than Westwood Lake. Its current Consequence Classification is "Very High" (between 10 and 100 people might die), yet it would flood into a rural/semi-wilderness river valley (Nanaimo River). The last dam safety inspection was done in 2001. South Fork dam falls short of the new Dam safety Regulations and will require an upgrade soon.

Inundation Map, Lower Nanaimo River (dated November 1990) by Klohn Leonoff Ltd for Greater Nanaimo Water District, is thought to show flooding in Cedar from a breach at both Jump Creek and South Fork Dams, but this isn't obvious. Flooding from South Forks would reach the Trans Canada Highway at Nanaimo River bridge after 18 minutes. Maximum water elevation would be 26 metres, achieved after 36 minutes, and maximum water depth would be 15 metres. In half an hour it would be past the Cedar

Road bridge heading for the Nanaimo River estuary. The flood would take almost two hours to reach the maximum water elevation (and maximum depth) of 12 metres.

About 50 buildings in Cedar are shown covered by the flood, and part of the airport runway. Cedar village itself seems largely unaffected. Despite the obvious volume of water, there seems little reason to qualify up to 100 fatalities. However, the Regional District of Nanaimo has grown since 1990.

Jump Creek Dam was built in 1974. It now holds up to 18-million cubic metres of water. The height might be increased to hold even more. It is a zoned earthfill embankment and saddle dam. Its height is 25 and 6.7 metres and width 464 and 154 metres. A safety review has never been done. Its current dam failure consequence classification is "Very High." It too has had problems. The following quote is taken from Will Jolley, Senior Dam Safety Officer, Victoria at the 6th December 2012 meeting.

"The City of Nanaimo has a long history of fixing up their dams and I would say in the 1990s the priority was the Jump creek Dam which is the main supply dam and there were some significant issues and problems with the dam despite the fact that it was built in the 1990s. It was a long process; I'd say a good ten year process that the city went through to go from recognizing a whole series of problems with the Jump Creek Dam to a final really, really good solution that they came up with. It was a huge public spillway, which we were uncomfortable with. It was an enormous spillway that was a flat gate in the service spillway, which we were uncomfortable with and there was a whole series of things that had to be worked out together, including seismic standards. There was a problem with the low level outlet that caused damage so severe that the dam failed. The city took about 10 – 12 years to come to a final design and construction that everyone was happy with, so it didn't happen overnight. We knew there was a problem with that

dam but we knew we had faith that the city would get there, which they did. I don't know what costs were, but they were substantial. That was the focus at the time, the water supply to the city, which is of course something that everyone in the city needs. After the Jump Creek Dam was fixed, Nanaimo looked at their dams as a whole system and they have a good safety program."

This shows that Dam Safety Branch can be very flexible if they want. There is no mention of these issues in any of the available literature about the city water supply; perhaps it's something of an embarrassment. It may explain the reason for the timing of the 1990 Nanaimo River flood inundation study and why there was no new study of the Colliery dams until 2003.

Fourth Lake Dam was built in 1952 to provide water for Harmac Pulp Operations and is privately owned. The concrete faced, rock fill dam structure ensures that there is sufficient flow in the Nanaimo River for the mill to take up to 330 million litres of water per day from the Nanaimo River. It is a very large lake. No details were readily available, but, by comparison, the city takes up to 94 million litres per day from its dams. It has been considered for use by the city. In 2011/2012, SRM Projects Ltd conducted a dam safety review.

"The current Cedar Main Street Design Project Draft Plan includes land use policies and development guidelines intended to guide future development and reflect residents long term vision for the community." Also of note is the number of newly built residences near the river and along Nanaimo River Road. Perhaps, this is a useful point to consider an updated inundation study to assist planning and identify high points. Besides a breach of South Fork and Jump Creek Dams, a worst case scenario might include a breach of the Forth Lake Dam too, as well as a major flooding event. One wonders what the combined impact might be at the estuary of flood surges of both Nanaimo River and Chase River.

The author is aware that Fourth Lake is privately owned and such a study would require cooperation from the owner. However we should be concerned only with public safety issues.

8 – CONCLUSIONS

The Middle and Lower Chase River Dams are currently classified as “Extreme” along with 38 others, out of 1649 in the province. They are the only dams with the label “Extreme – Large, Level 1 – Alert”. Considering the size and location of some of these dams, this circumstance just seems surreal.

CON as a dam owner is clearly responsible for the safe operation of their dams. Under the BC Water Act a dam owner is liable for any damage to land and property resulting from failure of their dam. That means us, the taxpayers. While the Dam Failure Consequence Classification system became increasingly complicated, we lost our opportunity to rehabilitate the dams to a healthy condition for a reasonable outlay of money.

For a decade, competent engineers have warned the City with their reports that the Colliery dams needed fixing, and they appear to have been mostly ignored. Without searching records, we don’t know if Staff passed these warnings on to Council.

With criteria provided by the City, the inundation study engineers developed a population of 1810 and 1883 for day and night respectively within the flood boundary. The author believes that he has proven from independent sources that these are inflated figures. They may be anything from a third up to twice what they should be. His figures from separate sources are: 1033; 669 & 1227; 449 & 915; 587 & 1076.And since the PAR helps to decide the fatalities, so the consequence classification is affected. It would have been useful to see how the fatalities were actually arrived at.

If the process is scientific it should be replicable. Otherwise it's just an educated guess, an opinion.

Susan Clift, Director, Engineering & Public Works and Bill Sims have authored a Report to Council regarding "Colliery Dams – Cost of Alternatives to Removal" dated 6th May 2013 states, under Risk, "……John Barsby Secondary School, Little Ferns Daycare and up to 340 residences and 1900 people impacted." 340 residences translates (times 1.2 or 2.2) into 408 (day) or 748 (night) population (the permanent population). This may be an accurate count, but the 1900 people figure persists. Adding the travelling population and those on school grounds is (408+ 773 = 1181 daytime) and (748 + 15 = 763 nighttime). 1900 – 1181 = 719. 1900 – 763 = 1137. The 719 and 1137 figures are not accounted for.

Nanaimo emergency personnel went door to door delivering packages of information on warnings and evacuation to homes within the inundation boundary. That must have given them an accurate number of housing units in the area and the people occupying them. However, emergency program volunteers expect 1800 or so people at Bowen and Beban parks facilities in an evacuation. If this investigation is accurate, there should be an obvious difference between the two figures.

Hydraulic Modeling

All of the following studies used the stated one-dimensional computer models:
"Dam Safety Investigation Hydrology Studies & Inundation Mapping" by Klohn Leonoff Ltd Consulting Engineers, 1990 (Jump Creek and South Fork dams) – used DAMBRK.
"Chase River Dams Incremental Damage Assessment" by Water

Management Consultants, (all four Chase River dams), 2002 – used Un Known.
"Middle & Lower Chase River Spillway Hydrology Study" by Water Management Consultants, 2002 – used HEC-RAS & HEC-HMS
"Westwood Lake Dam Inundation Study" by Water Management Consultants, 2004 – used HEC-HMS & MIKE-11.
"Chase River Dams Breach Flood Inundation Study by Associated Engineering, 2010-2012 – used MIKE-11 & MIKE-URBAN. The latter also used MIKE-21, a two-dimensional computer model.

One dimensional programmes are incapable of estimating lateral variations in flood levels across a cross section. Hydrologic analysis of river channels is limited to flows below the top of the bank. They are unable to account for lateral outflows and alternate flow paths above the top of the cross section.

Clearly, using two-dimensional modeling adds a quite different dimension to the process. Compare the results of the 2002 and 2012 Chase River dams studies. I propose that Westwood Lake Dam (including the Millstone River and the Cat Stream) should be remodeled using a two-dimensional approach. After all, its study is almost a decade old. Likewise, the Jump Creek and South Fork dams whose inundation studies are almost a century old should be remodelled. It is the safe thing to do if the City and its surroundings intend to keep on growing.

Many local people conversant with the Colliery Park lakes have a hard time transposing those relatively small lakes into a major flooding disaster in Harewood plain below. We are expected to accept the findings of experts and ignore our own senses, even when the facts are questionable. Of course we are concerned about safety but we don't want the wool pulled over our eyes. Harewood Neighbourhood Plan has been in gestation for a year or two. It is clear from the recent open house that it is mostly about increasing

the density of residential properties and developing more commercial building too. We note that Bruce Avenue south of Fifth Street is destined to become a corridor, stretching back half a block from the road with up to six story commercial and residential developments. Also, a renewed commercial node is proposed for the northwest side Bruce Avenue and 8th Street. Apparently a large grocery supply warehouse is set to redevelop the old Cooperative building. The flood plain cannot be much more developed while the dams are still considered a risk. Furthermore, if the John Barsby High School is ever shut down, along with the park, there could be a whole block of public land to sell off to developers.

For safety, we could simply limit future density in the actual flood plain and river course to zero growth, and perhaps encourage more gardening in what was farm land.

If, for safety's sake, Westwood Dam has to be removed and the lake drained, there are seven square kilometers of rich former farm land that could be used to assist our community food security. Perhaps the city could rent out plots.

The author's certain preference would be to save both Colliery dams. If for safety reasons that really isn't possible without a horrendous amount of money (because we have already overspent) then we'd like to know that the decision was arrived at fairly, and that a self serving agenda wasn't the reason for their demise.

If tens of thousands of Chinese visitors are likely to visit Nanaimo soon, it might be wise to save a tranquil lake area as an attraction.

9 – GLOSSARY OF TERMS

Probable Maximum Flood. The largest flood that may reasonably be expected to occur at a given point on a stream from the most severe combination of critical meteorological and hydrologic

conditions that are reasonably possible on a particular watershed. This term identifies estimates of hypothetical flood characteristics. PMF has an approximate probability of a 10,000 year return period.

100-Year Flood. Is a flood event that has a 1% probability of occurring in any given year. It has a return period of 100 years. There is a chance in 100 that this flood flow level will be equaled or exceeded in any given year.

1000-Year Flood. Has a 0.1% chance of occurrence.

Canadian Dam Association. Is a group of dam owners, operators, regulators, engineers and others who share the goal of advancing knowledge and practices related to dams, consistent with social and environmental values. Our members are involved with all types of dams, including those used for irrigation, hydroelectric power municipal water supply and mining operations.

Dam Failure Consequence Classification (with Loss of Life): Low (No possibility), Significant (Low possibility for multiple), High (10 or less), Very High (100 or less), Extreme (More than100).

Abbreviations

AE = Associated Engineering
CDA = Canadian Dam Association
CON = City of Nanaimo
DSR = Dam safety Review (mandated every 7 or 10 years)
KCB = Klohn Crippen Burger
PAR = Population At Risk
PMF = Probable Maximum Flood
RFP = Request For Proposals
RFQ = Request For Qualifications
WMC = Water Management consultants

10 – REFERENCES & SOURCES

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All italics are the authors, added for clarity.