MINERAL RESOURCES BRANCH

High Water Levels and Associated Flooding on the Margins of Catalone Lake, Cape Breton County, Nova Scotia: Coastal Hazard Assessment and Options for Remedial Action

P. W. Finck

Open File Report ME 2013-002

Report prepared by P. W. Finck, P. Geo.

NOVA SCOTIA
Natural Resources

Signature:
Date: June 27, 2013

Halifax, Nova Scotia

January 2014

High Water Levels and Associated Flooding on the Margins of Catalone Lake, Cape Breton County, Nova Scotia: Coastal Hazard Assessment and Options for Remedial Action

P. W. Finck

Introduction

Catalone Lake is located southwest of Mira Bay in Cape Breton County, Nova Scotia (Fig. 1). For several years property owners along the edges of Catalone Lake have reported issues with flooding due to high lake levels caused by blockages of the lake's outflow at Catalone Gut. In late August or early September 2012, Don Feldman (NSDNR) requested that I visit Catalone Gut, view the blockage issue where the lake discharges under a Nova Scotia Department of Transportation and Infrastructure Renewal

Figure 1. *Air photo of Catalone Gut Beach and Catalone Lake, Cape Breton County. Photograph is from 2009.*

(TIR) bridge, and attend a meeting the following day to provide my opinion about the drainage issues facing the landowners. The meeting was held in early September 2012 at the Municipal Building in Sydney and was chaired by the Honourable Alfie MacLeod, MLA. In attendance were various landowners, municipal, federal and development agency representatives, and a large number of provincial government representatives from many different departments, including the departments of Natural Resources (NSDNR) and Transportation and Infrastructure Renewal (TIR).

A wide ranging discussion was held during which I provided input on technical issues related to the blockage. The local residents expressed a desire to find a permanent solution to the blockages so that the lake would not flood their properties and would again become intertidal, as they contended it had been in the early- to mid-1900s. Residents indicated that it had been possible to take small boats in and out of the lake during suitable tide levels. They also wanted to preserve the flora and fauna associated with the brackish lagoon nature of the lake, which has reportedly become increasingly fresh in recent years under a reduced tidal regime. Regional staff of NSDNR disputed the contention of easy boat movement in and out of the lake and the degree of past tidal influence into and out of the lake. It was my understanding from the meeting that TIR has cleared blockages when they threatened the provincially owned bridge and this, in combination with municipal funding to remove blockages, has provided temporary solutions in the past. Funding, jurisdictional issues and liability seemed to be areas of concern and contention.

The purpose of this report is to examine geological and coastal processes that influence blockages of the tidal channel that incises the Catalone Gut barrier beach and connects Catalone Lake to Mira Bay. It is important to note that I did not investigate the landowners' claims of property flooding as a result of high water levels in Catalone Lake. This claim was not in dispute during the September 2012 meeting so it is accepted as factual in the geological analysis and subsequent writing of this report

Local Geology

Overview

The properties affected by flooding and drainage problems are located along the margins of Catalone Lake. Catalone Gut barrier beach separates Mira Bay from Catalone Lake (Fig. 1). The beach is composed of sand in the lower shoreface and sub-tidal zone, and by sand, coarse gravel and cobbles in the upper shoreface and storm ridge (Fig. 2). The shoreface and storm ridge sediment is highly mobile due to a strong west- to northwest-flowing longshore drift current.

Beaches and shore cliffs around Mira Bay are eroding and migrating landward in response to post-glacial sea-level rise and land subsidence. In this area relative sea level has risen approximately 0.3 m (~1 ft.) over the last century, based on the tide gauge record at North Sydney. Mira Bay Drive is built along the top of Catalone Gut Beach and serves to stabilize the beach, preventing it from migrating landward into the lake in response to sea-level rise. This migration would occur naturally during large storms when sediment is eroded from the front of the beach and washed over the top and back of the beach into the lake. As this process continues over time the elevation of the top of the beach increases, keeping pace with sea-level rise, and the back of the beach migrates landward into the lake. The lake level also keeps pace with sea-level rise. This would naturally cause lakeshore erosion and, where the topography is low, it would increase the frequency and severity of flooding.

Catalone Lake is fed by seven streams, which can be seen on the 1:150 000 scale maps of the Nova Scotia Atlas (Service Nova Scotia, Nova Scotia Geomatics Centre, 2010). The streams flow from surrounding uplands that reach an elevation in excess of 75 m. Fresh water inflow to Catalone Lake is sufficient to raise the level of the lake so that it overflows Catalone Gut barrier beach at the Mira Bay

***Figure 2**. Photograph showing sediment composition of the foreshore and beach ridge.*

Drive Bridge (Fig. 3). Without the presence of the former S & L Railway bed and Mira Bay Drive, creating a dam along the top of Catalone Gut beach, water accumulating in the lake would: (1) flow over the top of the beach in one or more shallow, wide channels or (2) cut a deeper, narrower incised channel through the top of the barrier beach. It is unlikely that water from the lake would simply seep out through the beach as there is no evidence of that occurring at present. Given the amount of outflow from the lake into Mira Bay observed in September 2012, this would not seep through the beach without ultimately causing erosion and breaching of the barrier beach. In a natural state I believe that an incised channel is the most likely scenario. The width vs. depth of the channel and the effect of the tide cycles on the daily lake water levels are unknown. In addition, the degree of natural blocking of an incised channel cannot be estimated.

Historical Lake Drainage at the Catalone Gut Beach Bridge

Figure 4 is part of an air photograph taken sometime between 1931 and 1939, which shows the drainage configuration out of Catalone Lake at that time. Close examination of the image indicates that when the photo was taken discharge to the ocean on the seaward side of the S & L Railway bridge occurred through a narrow channel cut through the upper shoreface and storm ridge. Water depth in the channel cannot be estimated from the air photograph, but would have varied based on the daily diurnal tide cycles. The channel under and between the S & L Railway and Mira Bay Drive bridges appears to be wider than the present width of the channel (Fig. 5). On the landward side of Mira Bay Drive the extent of the flood-tide dominated bar (outlined by the yellow dashed line, Fig. 4) appears to be similar in area to that observed in the fall of 2012 and to that documented by the 1954 and 2009 air photographs (Figs. 6 and 1).

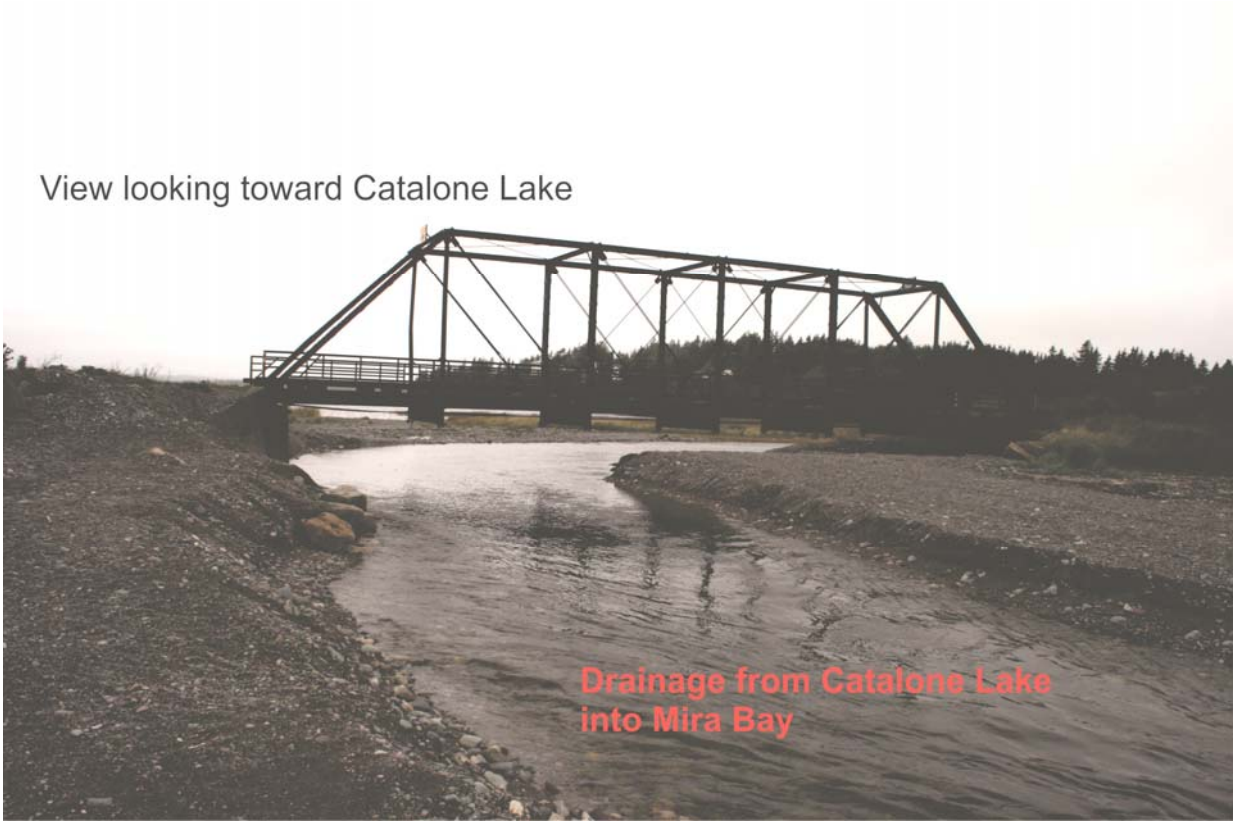

***Figure 3**. Photograph showing the drainage channel from Catalone Lake looking landward toward Mira Bay Drive Bridge.*

In the 1930s there is evidence of major human intervention controlling the drainage across and/or around the flood-tide dominated bar (Fig. 4). On the southwest end of the bar a man-made, linear, positive relief topographic feature (labeled as “bridge or dam”, Fig. 4) is present. It cannot be determined from the photograph whether this is a bridge or if it is a dam built across the channel to redirect the outflow of the lake water. The image also shows an excavated trench extending approximately 300 m across the bar into the lake (labeled “dredged channel”, Fig. 4). Based only on this image, various interpretations are possible. I believe, however, that the main channel may have been dammed (the dam also acting as a bridge). The trench was excavated to reroute the discharge from the lake more directly toward the rail and road bridges. Compared to the natural channel, the narrower, and what appears to be deeper, trench would have created a higher velocity discharge of water out of the lake. This would have had two possible effects: (1) larger (coarser) sediment could move through; and (2) blockage of the channel across the upper shoreface and storm ridge would have been reduced. It would also have allowed easier boat access to and from Mira Bay during times of high water level in the lake (including during high tide), and may have created a greater tidal influence in Catalone Lake.

In the 1954 image (Fig. 6), the bridge or dam is still present. It appears, however, that the natural channel has re-established flow around the south end of the bridge/dam. The trench shown on the 1930s air photograph is mostly filled in. A narrower and shallower remnant of a dredged channel is located directly off the end of the dam or bridge. There are six linear, dredged trenches on the southeast side of the 1954 image. They terminate in the emerged portion of the flood tide dominated bar and do not connect with drainage under the bridges. Given the fan-shaped orientation of the channels I believe that they were created by a stationary piece of equipment sitting at the apex of the fanned channels. The equipment may have been a dragline type of dredge used to remove material for commercial purposes.

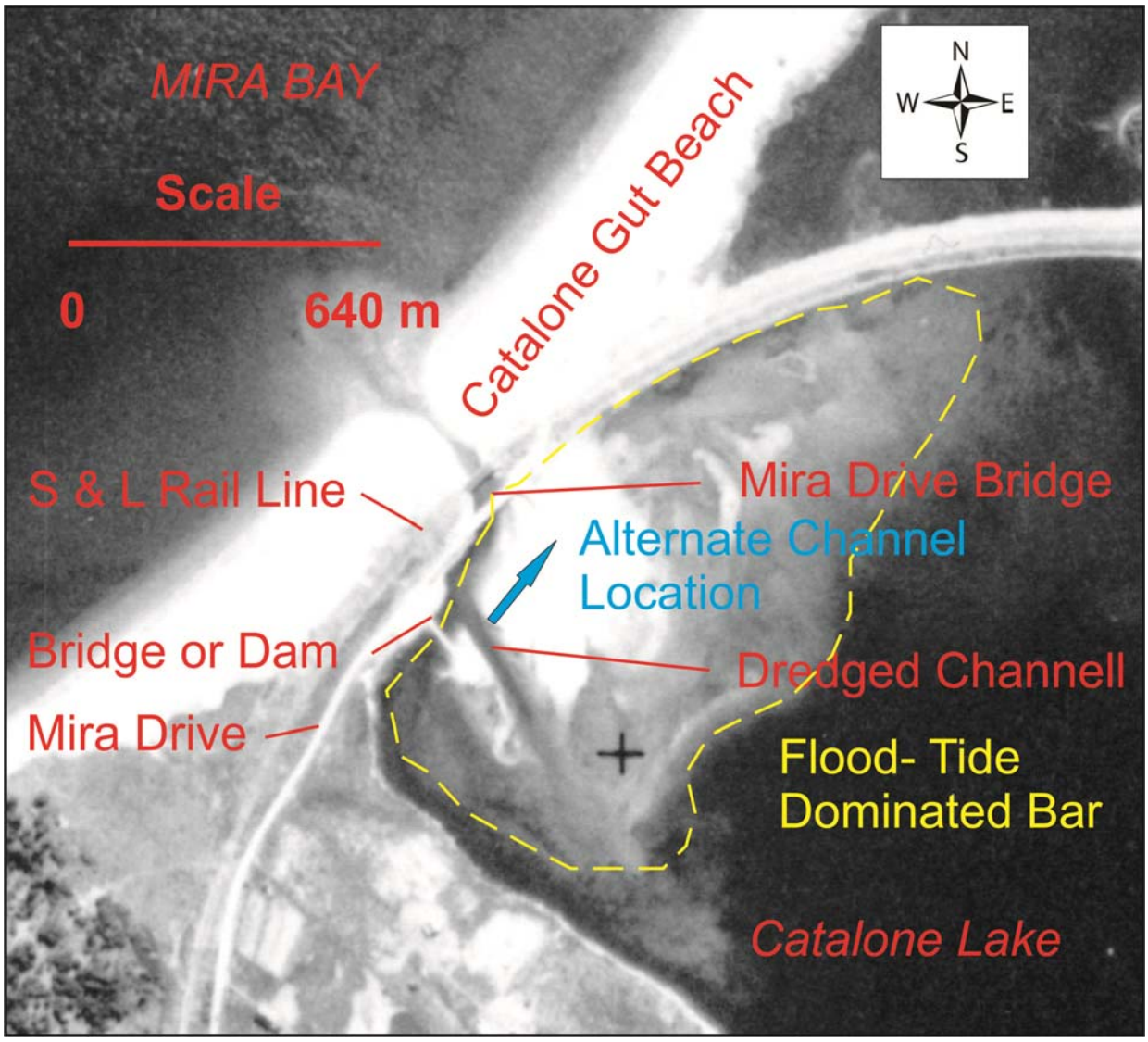

Figure 4. *Air photograph of Catalone Gut Beach taken sometime between 1931 and 1939.*

In Fig. 6 there does not appear to be any direct drainage connection between Catalone Lake and Mira Bay. This may be a result of temporarily blocked drainage following a particularly severe storm, the lake level may have been very low, or given the poor resolution of the image, there could have been a narrow drainage channel along the edge of the bar and Mira Bay Drive that is not visible. Based on examination of the 2009 air photograph (Fig. 1), and my field observations made in September 2012 (Fig. 7), it is my opinion that the drainage channel connecting Catalone Lake to Mira Bay is well developed with respect to the historical norm. However, the natural drainage channel is wide and shallow. In addition the channel is highly sinuous, making two 90 degree turns before exiting under the Mira Bay Bridge and flowing across and through the storm ridge and upper beach face of Mira Gut Beach. This means that tidal influence is reduced in Catalone Lake and the outflow channel is more susceptible to blockages since the carrying capacity of the water flowing toward and into Mira Bay is reduced.

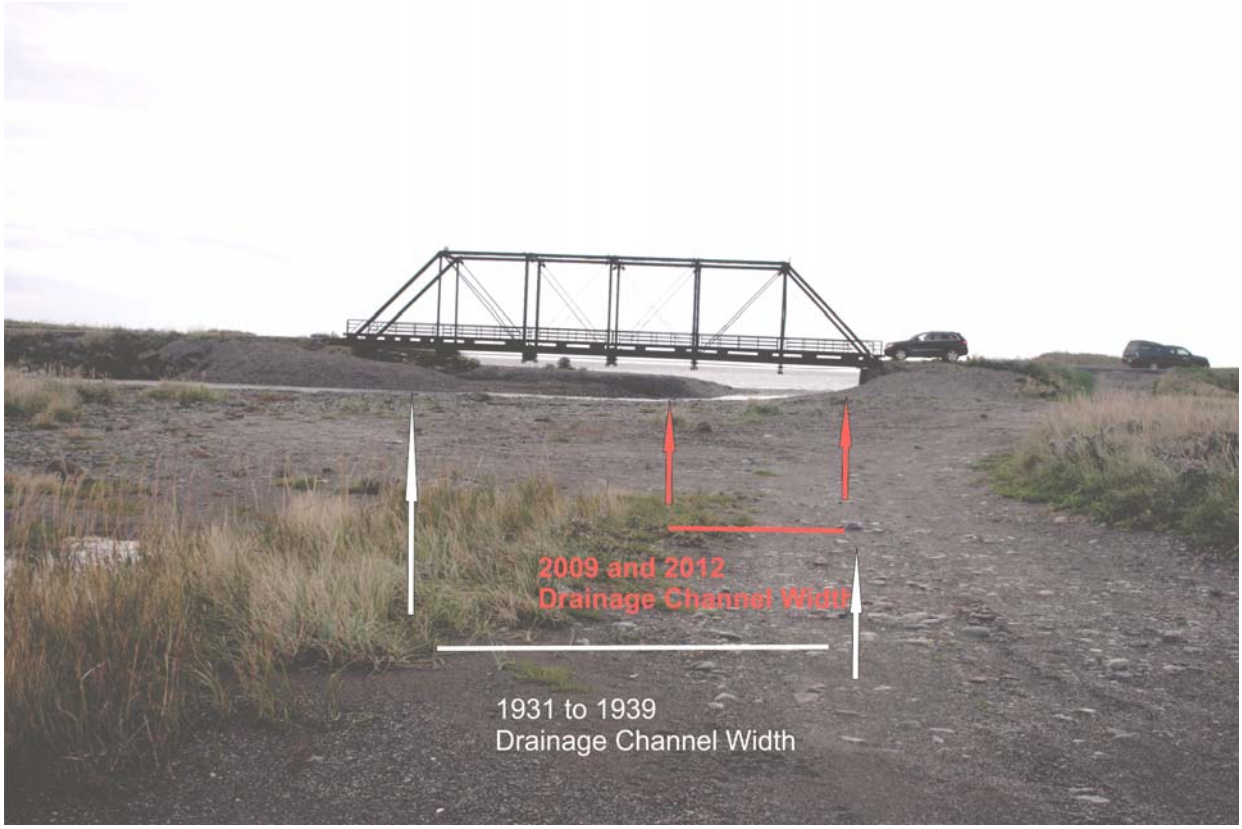

Figure 5. *Photograph showing the narrow drainage channel under Mira Bay Drive Bridge, looking seaward from the flood-tide dominated bar.*

Recommendations

Background

Blocked drainage out of Catalone Lake is not a recent phenomenon. I believe it occurred repeatedly during the Twentieth Century and will continue in the future. If Catalone Gut Beach had a restricted sediment supply, as sea level rose energy levels would increase on the beach face and the beach would erode. At that point Mira Bay Drive would need to be armored and there would be ever increasing overtopping of the road during storms. At some point energy levels would be high enough that the flood-tide dominated bar would be eroded and driven further into the lake, lake levels would be higher in response to the rising sea level, and a deep, free-flowing channel would be established between Catalone Lake and Mira Bay. Catalone Lake would become an artificial salt water tidal lagoon due to the presence of Mira Bay Drive. However, there is a large volume of sediment moving north and northwest along the shore of Mira Bay due to coastal erosion of soft bedrock and unconsolidated glacial sediment, as well as transport by a strong longshore drift, which maintains Catalone Gut Beach. This sediment supply will serve to repeatedly block the outflow of Catalone Lake and sustain the flood-tide dominated bar.

Sea level is approximately 0.3 m higher now than it was circa 1910. Thus, at times when there are astronomical high tides, and if the opening to Catalone Lake from Mira Bay is large enough for the incoming tide to fill the lake, then the high water level of Catalone Lake will be approximately 0.3 m higher than it was circa 1910. An absolute maximum lake level depends on the coincidence of an astronomical high-high tide (e.g. a spring tide), a period of high runoff into Catalone Lake, a significant

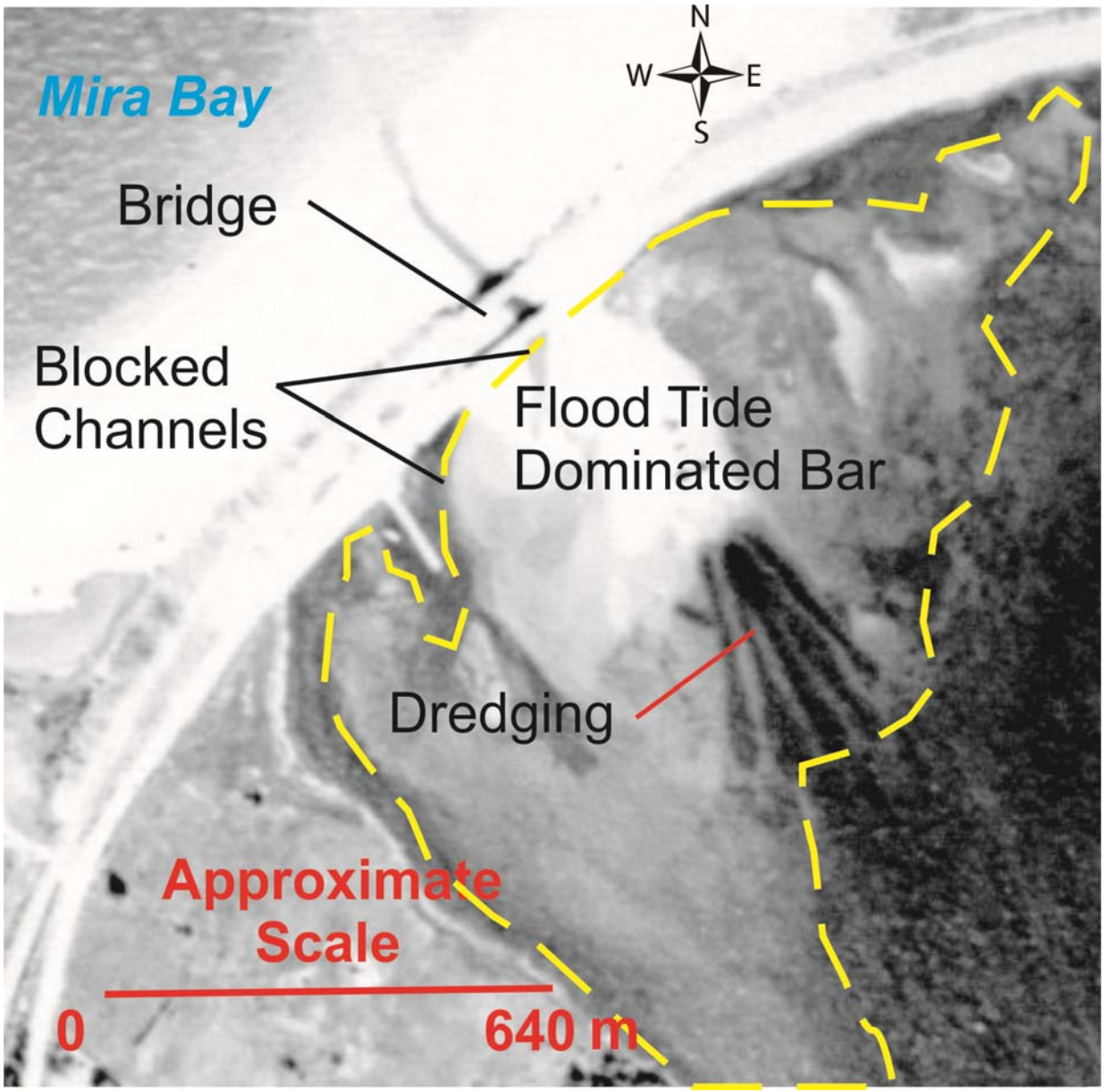

Figure 6. *1954 air photograph of Catalone Gut Beach.*

storm surge, and a strong easterly wind causing wave set-up on the west side of Mira Bay. There are too many variables and it is beyond the scope of this report to provide a definitive maximum potential water level for Catalone Lake. Given this combination of effects, however, it is my opinion that residents could experience a 1 to 1.5 m lake level above what would be considered as a typical 'lake flood level'. This, of course, would have a direct impact on fixed infrastructure, and in particular any older infrastructure.

Periodic blockage of the drainage channel between Catalone Lake and Mira Bay is a natural process, and in my opinion there is no long-term solution that does not involve engineering. Engineered solutions would only be a partial fix, have inherent drawbacks or risks, and would require long-term periodic dredging. I wish to emphasize that readers should note that the following suggestions are intended to be conceptual in nature and further engineering study and design would be required before any construction

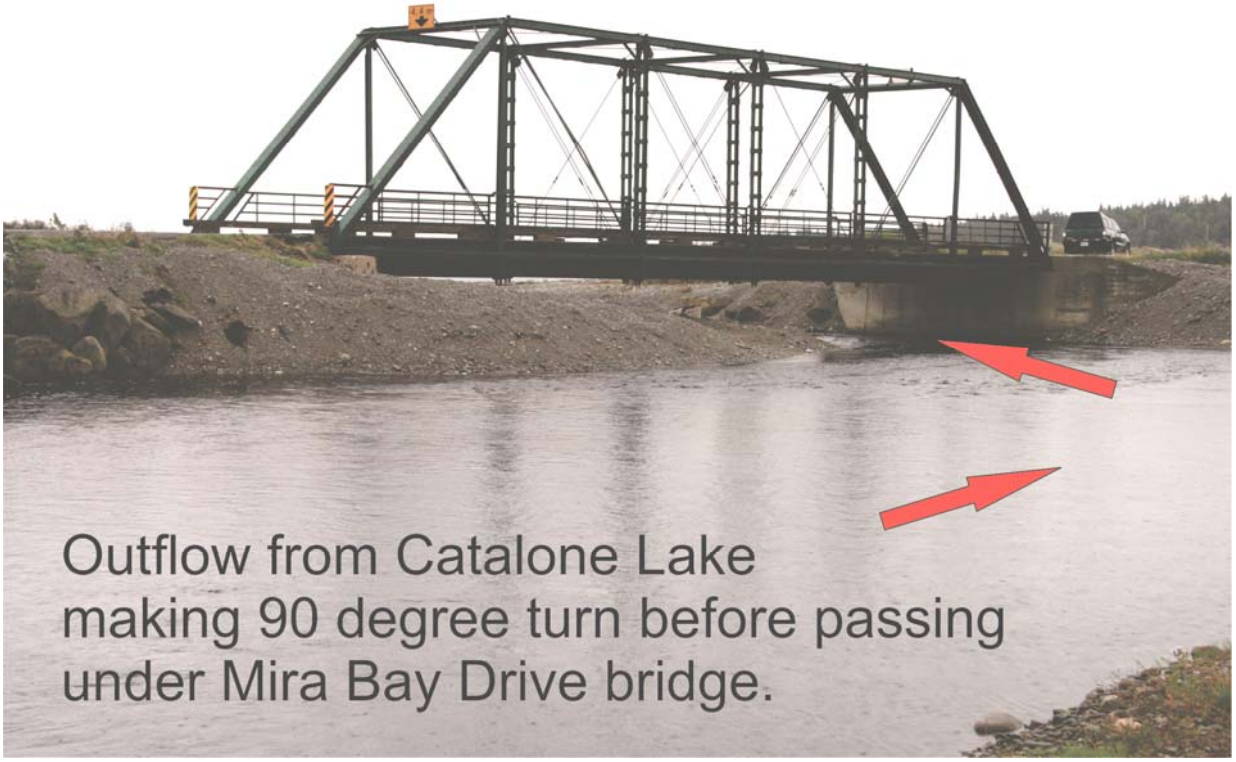

Figure 7. *Photograph illustrating the wide, shallow, meandering nature of the drainage channel on the landward side of Mira Bay Drive Bridge.*

or dredging was undertaken. The concepts do not consider any cost–benefit analysis, specific environmental impact concerns, address the question of who would pay, consider policy implications such as whether government should fund this type of activity and/or whether it is a wise use of limited government resources.

Engineered Solutions

A possible solution to the issue of flooding is dredging and complete removal of the flood-tide dominated bar in Catalone Lake, leaving deep water on the lake side of Mira Bay Drive Bridge. This would allow direct drainage of the lake under the bridge, cutting a deep channel across Catalone Gut Beach. However, over time storms would drive sediment landward from the beach into the lake, filling the depression, and re-establishing the present drainage pattern. The time frame for this to occur is unknown and would in large part depend on the frequency and severity of storms. In the meantime, the dredging would likely result in a rapid drop in lake level that would fluctuate with the tide and seasonal runoff. The influence of tides would be increased in Catalone Lake, whereas fluctuations in water level due to seasonal and rainstorm specific run-off would be likely reduced. This could increase the risk of flooding during a high–high astronomical tide coinciding with a period of high runoff into Catalone Lake, and potentially a significant storm surge. A significant concern would be whether the higher velocity current, and thus more erosive current, passing under the bridge would undercut the abutments. In addition, the current would likely be strong except at the time when the tide turns at flood and ebb. There could also be significant but temporary beach erosion immediately seaward of Mira Bay Drive Bridge as sediment from the beach is flushed in during the dominant flood tide and flushed back out during ebb tide.

A second possible solution would be to wall both sides of the outflow beneath and seaward of the bridge with armour stone. The wall would need to extend to a depth equal to the base of the gravel – cobble upper foreshore. The sides of the walls should be smooth to reduce turbulence. The outflow should be restricted in width to increase the velocity of the water flowing out of Catalone Lake (Fig. 3). The increased velocity would increase the size of sediment eroded by the moving water, hopefully to a point where the carrying capacity of the water exceeded the size of the largest cobbles in the beach ridge. This would enhance the ability of the lake outflow to clear the outlet of blocking sediment. This, however, would be limited by the flow capacity of the meandering channel at the end of the lake. To increase the effectiveness of this option a channel should be dredged through the flood-tide dominated bar directly opposite to the bridge, similar to the trench observed on the 1930s air photograph, but approximately 250 m farther to the northeast (Fig. 4). In this instance, the necessity to dredge sediment from the outlet channel across the beach ridge and from under the bridge would be replaced by the requirement to periodically dredge to keep the channel across the bar open, and probably also to dredge sediment from under the bridge. There is no guarantee that even with a narrower outlet channel across the storm ridge that severe storms wouldn't still periodically block the channel.

Conclusions

The present study supports the contention that drainage from Catalone Lake to Mira Bay has been periodically deeper and more vigorous in the past than at present, and that boats had been able to move through the channel between Catalone Lake and Mira Bay. However, at the same time, it also supports the contention expressed in the September 2012 meeting that boat movement in and out of the lake and the degree of free flow of the tidal influence into and out of the lake was more restricted than suggested by local residents. This apparently contradictory conclusion is based on the transient nature of the drainage channel, the discontinuities of human recollection, and what appears to be significant historical dredging and construction activity associated with the flood-tide dominated bar.

Both possible solutions described in the previous section would require periodic maintenance and dredging and thus may not represent a significant improvement over the present situation. It is also very difficult to determine the potential impacts of having a faster-flowing outlet with increased tide effects in Catalone Lake. Should an engineered solution be considered, it is advised that the local residents recognize that there could be unforeseen circumstances associated with such solutions.

Reference

Service Nova Scotia, Nova Scotia Geomatics Centre 2010: Nova Scotia Atlas, Sixth Edition; Formic Publishing Company Limited and the Province of Nova Scotia, Halifax, Nova Scotia, 144 p.