**HEROLD ENGINEERING**

February 12th, 2024 2360-002

Via email: finance@dbid.ca

Deep Bay Improvement District (DBID)
5031 Mountainview Road
Bowser, BC
V0R 1G0

Attn: Janine Sibley
Acting Deep Bay Improvement District Administrator

**Re: Deep Bay Improvement District - Water Tank Condition Assessment**

Dear Ms. Sibley:

Herold Engineering Limited is pleased to submit this report for the Condition Assessment of the Deep Bay water tank in Bowser, BC.

## 1.0 Background

The Deep Bay water tank is approximately 33' wide, 43' long, and 17' tall, with a partition wall inside the tank creating two water chambers. The structure, which was reportedly constructed in 1977, is made of reinforced concrete and the walls are one foot thick. The tank was designed to allow for future expansion; therefore, there is reinforcing steel bars projecting out of the walls and roof of both chambers on the south side which was left exposed for this purpose.

In 2009, Herold Engineering Ltd. (HEL) completed a brief visual assessment of the water tank and provided a letter summarizing the findings, dated September 28, 2009. The previous 2009 assessment reported that the tank was in serviceable condition but also noted concrete cracking and spalling. Further, it was recommended that concrete spot repairs, including crack repairs on the interior of the tank, be completed to limit potential future damage.

HEL visited the Deep Bay water tank on July 19th, 2023, to complete an updated condition assessment. The purpose of this assessment was to document the overall material condition of the tank exterior. HEL visited the Deep Bay water tank again on February 6th, 2024, to complete a review of the interior of the tank.

## 2.0 Limits of the Investigation

This investigation consisted of a visual, tactile, and sounding survey to assess the material condition of the concrete water tank. It was reported on site that the water within the tank suffers from contamination issues. However, this investigation did not seek to understand the causes of the contamination.

## 3.0 Observations

The following was noted:

1. Vertical cracks on the walls were observed on each side of the four corners of the building (see Photos 1-4).
2. Vertical cracks were also observed in the center of all but the west wall (see Photos 1-4).

3. It was noted that many exterior cracks have previously been repaired with a cementitious parging applied to the exterior surface of the tank. However, many of the previously repaired cracks appear to be leaking.
4. The cementitious parging was noted to be poorly bonded to the concrete walls in many locations.
5. It was observed that a previous repair to the north-east corner had been completed that involved thickening the concrete wall from the top of the footing to approximately 6' high and wrapped 5' wide in each direction around the corner (see Photo 5). It was noted that the top east face of this repair appears delaminated when sounded.
6. Exposed reinforcing steel was observed the be still present on the south side of the tank projecting out of the rood slab and walls. This was reportedly left to facilitate the future expansion of the tank's capacity (see Photos 2, 6, & 7).
7. It was observed that metal flashing was installed along the top of the north, east, and west walls. This was reportedly installed to prevent water from dripping down the wall, especially over the wall-roof slab construction joint. No flashing was installed on the south side of the tank as this side features exposed reinforcing steel (discussed above).
8. Vertical cracks were observed at each of the four interior corners of each tank some spanning the entire height (see Photos 11 and 12)
   a. These cracks ranged from 1-4 mm in width.
   b. The vertical cracks in the north-east and south-east corners of the building were previously repaired; however, these repairs appear to be cracked.
9. Cracks were observed on the roof of the tank which were also noted to be visible from the inside of the tank (see Photo 13 as an example).
10. Erosion to the concrete was observed inside the water tanks (see Photo 14 & 15 examples).
11. Corrosion of the existing concrete form ties was observed (see Photos 16).
12. It was noted that some of the ladder rungs providing access to the interior of the tanks have experienced minor corrosion (see Photo 16).
13. Cracks were observed between the bottom of the tank and the tank walls.
    a. It was noted that these cracks had been previously repaired in the east tank, however, these repairs appear to be cracked (see Photo 17 as an example).
14. While sounding the concrete inside the tank, it was noted that the concrete exhibited a dull sound. This is likely an indication of a weak surface layer of concrete, perhaps 3-5mm deep, which may have resulted from the cement dissolving due to prolonged exposure to fresh water.

## 4.0 Testing

HEL completed various tests on the exterior of the concrete water tank. Each of these tests corresponds to a particular potential deterioration mechanism of reinforced concrete structural elements. The tests and results are as follows:

### *a) Carbonation Testing*

As concrete ages, it absorbs carbon dioxide from the atmosphere. This process is known as carbonation. Typically, only the outer surface of the concrete is affected, but as time goes on the depth of the carbonation increases. Once the depth of carbonation reaches the depth of the reinforcing steel, the reinforcing steel becomes more susceptible to corrosion. Three (3) carbonation tests were completed on the water tank, Tests 1 and 2 were on the walls of the tank, and Test 3 was completed on the roof slab. The results are presented in Table 1 and Photos 8-10 are of the concrete samples after processing.

***Table 1** – Carbonation Testing Results*

| Test Identification | Core Diameter (mm) | Location | Depth of Carbonation (mm) |
|---|---|---|---|
| Carbonation Test 1 | 25 | East Wall, adjacent to existing repair | 1 |
| Carbonation Test 2 | 25 | West Wall, bottom north corner | < 1 |
| Carbonation Test 3 | 25 | Roof | 0 |

It is noted that since the depth of carbonation is less than the concrete cover, it is unlikely that concrete carbonation is cause for deterioration.

*b) <u>Chloride Testing</u>*

Like carbonation, the presence of chloride ions in concrete can promote the corrosion of reinforcing steel. There are two typical causes of chloride penetration in concrete. First, chloride penetration occurs when a concrete structure is exposed to a salty environment, such as ocean water or water contaminated with de-icing salts. Second, chlorides may have been added to the concrete at the time of construction.

According to the American Concrete Institute (ACI), reinforcement corrosion can occur once chloride concentration within the concrete pore structure reaches a minimum level – referred to as the chloride threshold. The chloride threshold is dependent on several physical and environmental factors; however, it is often considered to be ~0.15% by the mass of cement. Once the chloride concentration at the depth of the reinforcing steel reaches the chloride threshold, reinforcement corrosion may initiate. Chloride tests were completed at two locations on the walls of the water tank at various depths. The results of these tests are presented in Table 2:

**Table 2** – *Summary of Chloride Testing Results.*

| Location Description | Test No. | Depth (mm) | Mass of chloride (ug) per mass of concrete (g) | Mass of chloride (g) per mass of cement (g) | Chloride Concentration by Mass of Cement (%) * |
|---|---|---|---|---|---|
| East Wall, adjacent to existing repair | 1 | 0 -30 | <100 | <0.001 | <0.067 |
| | 2 | 30-55 | <100 | <0.001 | <0.067 |
| | 3 | 55-70 | <100 | <0.001 | <0.067 |
| West Wall, bottom north corner | 4 | 0-25 | <100 | <0.001 | <0.067 |
| | 5 | 25-50 | <100 | <0.001 | <0.067 |
| | 6 | 50-75 | <100 | <0.001 | <0.067 |

**Assuming a concrete unit mass of ~2350 kg/m$^3$ and cement content of 350 kg/m$^3$*

*c) <u>Rebound Hammer Testing</u>*

Rebound hammer testing is a method of non-destructive testing for estimating the compressive strength of in-place concrete. Two (2) rebound hammer tests were completed in conformance with *ASTM C805 Standard Test Method for Rebound Number of Hardened Concrete.* The results are presented in Table 3.

Table 3 – Summary of Rebound Hammer Test Results

| Test No. | Test Location | Average Rebound Number | Estimated Concrete Compressive Strength (MPa) |
|---|---|---|---|
| #1 | East Wall, adjacent to existing repair | 44 | 40.5 (± 6.5) |
| #2 | West Wall, bottom north corner | 43 | 39 (± 6.0) |

## 5.0 Discussion

The results of the carbonation and chloride testing do not indicate the presence of these deleterious substances within the concrete. Further, the rebound hammer testing estimates that the concrete compressive strength is more than 35 MPa, which is considered satisfactory for this application. While many of the existing parging layers on the exterior of the tank walls appear to be delaminated, and many of the repairs of the cracks on the interior of the tank appear to have cracked, this likely will not affect the performance of the tank in the short to medium term. Also, while the large repair on the north-east corner of the building appears partially delaminated, this repair appears to be performing satisfactorily.

It is our opinion that the tank appears to be performing satisfactorily and is in a serviceable condition. Therefore, it is expected that the tank can provide more years (10 – 15+ years) of service. It is however noted that this remaining life estimate is based on continued maintenance activities.

It was reported to HEL that the water tank suffers from water contamination issues. As previously discussed, this assessment did not consider the sources of potential contamination. However, if the contamination is deemed to be the result of water (contaminant) infiltration through the exterior walls or roof of the tank, then several solutions may be considered appropriate.

Many of the vertical cracks in the walls of the tank are permitting water to seep out of the tank. To seal these leaks, a relatively simple method may be to install a flexible sealant over the cracks and joints of the tank interior. This would involve routing out the cracks and construction joints prior to installing the flexible sealant. If a more aggressive solution is desired, then a liner could be provided on the interior of the tank to prevent water egress through the walls. As previously discussed on site, there are two potential membrane types which may be considered: a flexible polyurethane membrane or a cementitious membrane. While a cementitious membrane is likely to be longer lasting, a flexible membrane may provide better crack bridging capabilities. Regardless of the membrane system selected, the process will require an extended shutdown period (perhaps months) to complete the installation. If a membrane is desired, it is expected to cost approximately $140,000.

To limit water ingress from the roof, a torch-on membrane system applied to the roof could also be installed. This is expected to cost approximately $70,000.

Another source of water ingress into the concrete may be along the top of the south wall at the existing roof-wall connection where a notch and exposed rebar was built into the tank, reportedly to facilitate a future addition. If it is unlikely that any future additions to the tank will be carried out, it is recommended that the exposed rebar on the top south wall be bent parallel with the wall and additional concrete be placed to allow water to drain away from the structure. Furthermore, the exposed rebar projecting from the walls can be cut away. This work is expected to cost approximately $5,000 – 10,000. Figure 1 describes this repair.


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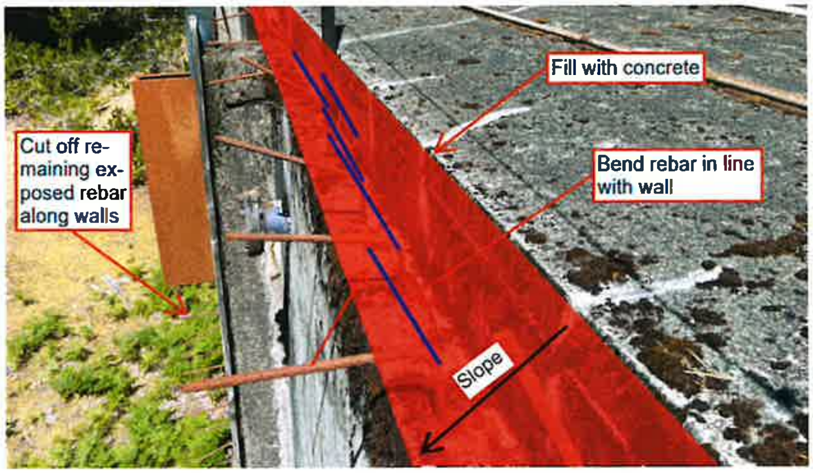


**Figure 1: Proposed South Wall Repair**

## 6.0 Recommendations

The water tank appears to be in a serviceable condition and can be expected to provide more years of service (10 – 15+ years).

The following is a list of recommendations to maintain the Deep Bay Water Tank:

1. Remove the exposed rebar projecting from the walls on the south side of the tank.
2. Engage a water specialist to determine the sources of water contamination.

If the source of water contamination is determined to be the result of water ingress through the roof or walls, and/or an extended service life is desired, the following remedial options may be considered:

3. Install flexible sealant in the joint and cracks.
4. Apply a membrane, either flexible or cementitious, inside the tank.
5. Apply a 2-ply SBS membrane to the roof of the tank.
6. Fill the notch along the top of the south wall with concrete as described in Figure 1.

## 7.0 Closing

Please contact us if you have any questions or would like further direction or help with the proposed recommendations.

Yours truly,

Per: HEROLD ENGINEERING LIMITED

Prepared By:

Martin Uhl, GradTech
Technologist

Reviewed by:

12 February 2024

Craig Appelman, P.Eng.
Materials Engineer

Permit No.
1000201

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|  | Photo 1 – A view of east side of the water tank. Note the vertical cracks near the corners as well as in the center. |
|  | Photo 2 – A view of the south side of the holding tank. Note the vertical cracks near the corners as well as in the centers. |

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|---|---|
|  | Photo 3 – A view of the north side of the holding tank. Note the vertical cracks near the corners as well as in the center. |
|  | Photo 4 – A view of gauge the west side of the holding tank. Note the vertical cracks near the corners. |



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|  | Photo 5 – A view of the existing repair on the north-east corner of the water tank. The red circle indicates the approximate extents of the delamination. |
|  | Photo 6 - A view of the exposed rebar on the south side of the water tank. |


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|  | Photo 7 – A view of the exposed rebar on the south side of the water tank. |
|   | Photo 8 – Carbonation Test #1 where the pink colour indicates where the concrete is not carbonated and the absence of colour indicates the presence of carbonation. |

Photo 9 – Carbonation Test #2, where the pink colour indicates where the concrete is not carbonated and the absence of colour indicates the presence of carbonation. Note, the lower right half of the sample was not tested as this portion of the sample was from too deep in the concrete to have experienced carbonation.

Photo 10 – Carbonation Test #3, where the pink colour indicates where the concrete is not carbonated and the absence of colour indicates the presence of carbonation.



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|  | Photo 11 – A view of the interior south-east corner of west tank. Note the top half of the corner appears to feature a crack. |
|  | Photo 12 – A close view of a typical crack in the tank corners. |



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|  | Photo 13 – An example of a crack in the roof of the tank which is visible from the inside of the tank. Shown is the north side of the west tank. |
|  | Photo 14 – An example of concrete erosion observed inside the tanks. |
|  | Photo 15 – An example of concrete erosion observed inside the tanks. |


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|  | Photo 16 – A view of the corroded ladder in the west tank. A corroded form ties is also visible (circled in red). |
|  | Photo 17 – An example of a failed crack repair between the bottom of the tank and the tank wall. |


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