

APPENDIX A
WSDOT Underwater Inspection Form



General Administration
STATE OF WASHINGTON

Capitol Lake Dam/5th Ave Bridge, Olympia, WA UNDERWATER INSPECTION REPORT



Prepared for:

**Washington Department of
General Administration**

Prepared By:



710 Second Ave, Suite 720
Seattle, WA 98104
Tel: (206) 622-0222 • Fax: (206) 622-4764

June 22, 2007

Inspector Andrew Thomas / Shawn Hardy		Date 5/24/07
Bridge Number GA002	Bridge Name CAPITOL LAKE	
Bridge Type Dam w/ concrete girders, deck, pier walls, spillway	Waterway Name Budd Inlet	
Dive Objective Visual/tactile inspection of accessible substructure elements.		
Diving Operation		
Type of Operation <input type="checkbox"/> SCUBA <input type="checkbox"/> Snorkel <input checked="" type="checkbox"/> Other <u>Surface Supplied Air</u>		
Equipment		
	Suit	<u>Dry suit</u>
	Air Supply	<u>LP Compressor</u>
	Site Access	<u>Boat</u>
	Inspection Tools	<u>lights, trowel/scrapper</u>
	Repair Tools	<u>n/a</u>
	Repair Materials	<u>n/a</u>
Condition		
Water <input checked="" type="checkbox"/> Salt <input type="checkbox"/> Fresh <input type="checkbox"/> Brackish Temperature <u>50</u> °F Visibility <u>15 ft</u>		
Surface <input checked="" type="checkbox"/> Calm <input type="checkbox"/> Choppy <input type="checkbox"/> Rough		
Surf <input checked="" type="checkbox"/> Small <input type="checkbox"/> Medium <input type="checkbox"/> Large <input type="checkbox"/> N/A		
Tide <input checked="" type="checkbox"/> High <input type="checkbox"/> Low <input type="checkbox"/> Flood <input type="checkbox"/> Ebb <input type="checkbox"/> N/A		
Current <input type="checkbox"/> Fast <input type="checkbox"/> Moderate <input checked="" type="checkbox"/> Slow Velocity <u>0-0.5</u> ft/sec.		
Weather <input checked="" type="checkbox"/> Sunny <input type="checkbox"/> Cloudy <input type="checkbox"/> Overcast <input type="checkbox"/> Rain Air Temperature <u>70</u> °F		
Thermocline Temperature <u>n/a</u> °F Depth <u>n/a</u> ft.		
Diver Checks		
<input checked="" type="checkbox"/> First Aid Equipment on Site <input checked="" type="checkbox"/> Physical Condition of Diver(s) Checked <input checked="" type="checkbox"/> Communication for EMS <input checked="" type="checkbox"/> Communications for Diver(s) Checked <input checked="" type="checkbox"/> Dive Gear Inspected <input checked="" type="checkbox"/> Team Briefed and Understand Dive Plan <input checked="" type="checkbox"/> Air Source Checked <input checked="" type="checkbox"/> Special Site Hazards Noted <input checked="" type="checkbox"/> Lockout/Tag Out of dam controls completed <input type="checkbox"/>		
Dive Plan and Dive Team Procedures		
<p>The dam shall be investigated using a three-member dive team: one supervisor to monitor rack box and take notes, one diver, and one tender/standby diver. Primary breathing will be conducted using Surface Supplied Air (SSA) dive equipment, which will be supplied by an low pressure (LP) air compressor from within the dive boat. Dive supervisor will accompany maintenance staff for lockout/tag out of all pump electrical and mechanical related switches that could initiate radial gate movement. Dive logs for each diver will be maintained at the site. Pre-dive briefing and checklist, equipment procedures and checklist, emergency procedures, specific procedures for tools, and job safety analysis (JSA) will be reviewed. At the end of the dive, physical assessment of the diver(s) will be made and a post-dive briefing will be performed.</p>		

Dive Schedule					
Dive No.	Entry Time	Exit Time	Total Time in	Maximum Depth	Remarks
1	10:13	12:20	2:07	18 ft	Andrew Thomas in water.
2	13:00	14:01	1:01	15 ft	Shawn Hardy in water.

Dive Narrative

Divers inspected all accessible submerged components and relayed messages to dive supervisor. Bands of marine growth, 12 by 12 inches, were scraped at intermittent locations for closer inspection of concrete surface. Divers noted miscellaneous spalls, cracks, and debris accumulation.

Dive Team Members

Michael Hemphill, P.E.

(Print Name)

Andrew Thomas

(Print Name)

Shawn Hardy

(Print Name)

(Print Name)

(Print Name)

Dive Supervisor

(Role)

Inspector, diver, standby diver/tender

(Role)

Inspector, diver, standby diver/tender

(Role)

(Role)

(Role)

Inspector Michael Hemphill, P.E.		Date 5/25/07
Bridge Number GA002	Bridge Name CAPITOL LAKE	
Bridge Type Dam w/ concrete girders, deck, pier walls, spillway	Waterway Name Capitol Lake	
Dive Objective Visual/tactile inspection of accessible substructure elements.		
Diving Operation		
Type of Operation <input type="checkbox"/> SCUBA <input type="checkbox"/> Snorkel <input checked="" type="checkbox"/> Other <u>Surface Supplied Air</u>		
Equipment		
	Suit	<u>Dry suit</u>
	Air Supply	<u>LP Compressor</u>
	Site Access	<u>Boat</u>
	Inspection Tools	<u>lights</u>
	Repair Tools	<u>n/a</u>
	Repair Materials	<u>n/a</u>
Condition		
Water <input type="checkbox"/> Salt <input checked="" type="checkbox"/> Fresh <input type="checkbox"/> Brackish Temperature <u>50</u> °F Visibility <u>15 ft</u>		
Surface <input checked="" type="checkbox"/> Calm <input type="checkbox"/> Choppy <input type="checkbox"/> Rough		
Surf <input checked="" type="checkbox"/> Small <input type="checkbox"/> Medium <input type="checkbox"/> Large <input type="checkbox"/> N/A		
Tide <input checked="" type="checkbox"/> High <input type="checkbox"/> Low <input type="checkbox"/> Flood <input type="checkbox"/> Ebb <input type="checkbox"/> N/A		
Current <input type="checkbox"/> Fast <input type="checkbox"/> Moderate <input checked="" type="checkbox"/> Slow Velocity <u>0</u> ft/sec.		
Weather <input checked="" type="checkbox"/> Sunny <input type="checkbox"/> Cloudy <input type="checkbox"/> Overcast <input type="checkbox"/> Rain Air Temperature <u>70</u> °F		
Thermocline Temperature <u>n/a</u> °F Depth <u>n/a</u> ft.		
Diver Checks		
<input checked="" type="checkbox"/> First Aid Equipment on Site <input checked="" type="checkbox"/> Physical Condition of Diver(s) Checked <input checked="" type="checkbox"/> Communication for EMS <input checked="" type="checkbox"/> Communications for Diver(s) Checked <input checked="" type="checkbox"/> Dive Gear Inspected <input checked="" type="checkbox"/> Team Briefed and Understand Dive Plan <input checked="" type="checkbox"/> Air Source Checked <input checked="" type="checkbox"/> Special Site Hazards Noted		
<input checked="" type="checkbox"/> <u>Lockout/Tag Out of dam controls completed</u> <input type="checkbox"/>		
Dive Plan and Dive Team Procedures		
<p>The dam shall be investigated using a three-member dive team: one supervisor to monitor rack box and take notes, one diver, and one tender/standby diver. Primary breathing will be conducted using Surface Supplied Air (SSA) dive equipment, which will be supplied by an low pressure (LP) air compressor from within the dive boat. Dive supervisor will accompany maintenance staff for lockout/tag out of all pump electrical and mechanical related switches that could initiate radial gate movement. Dive logs for each diver will be maintained at the site. Pre-dive briefing and checklist, equipment procedures and checklist, emergency procedures, specific procedures for tools, and job safety analysis (JSA) will be reviewed. At the end of the dive, physical assessment of the diver(s) will be made and a post-dive briefing will be performed.</p>		

Dive Schedule					
Dive No.	Entry Time	Exit Time	Total Time in	Maximum Depth	Remarks
1	10:14	11:00	0:46	18 ft	

Dive Narrative

Divers inspected all accessible submerged components and relayed messages to dive supervisor. No visible signs of deterioration of concrete wing walls were noted. Diver maintained a 20 foot minimum distance from the radial arm gates at all times due to currents through damaged seals.

Dive Team Members

Michael Hemphill, P.E.

(Print Name)

Andrew Thomas

(Print Name)

Shawn Hardy

(Print Name)

(Print Name)

(Print Name)

Inspector/diver

(Role)

Standby diver/tender

(Role)

Dive Supervisor

(Role)

(Role)

(Role)

Underwater Inspection Report

Bridge Number GA002	Route 05311	Agency/Owner General Administration	Date 6/22/07						
Bridge Name CAPITOL LAKE			Intersecting CAPITOL LAKE						
Inspector Michael P. Hemphill, P.E.		Identification No. G0611	Hours on Site 8						
Dive Contractor Moffatt & Nichol, 710 2nd Ave, Ste #720, Seattle, WA, 98104									
Diver Name Andrew S. Thomas		Diver Name Shawn D. Hardy							
Structure Type Concrete Girders and Deck		Substructure Type Concrete Abutments, Pier Walls and Bottom Slab							
Foundation Type Concrete Wing Wall Footings and Bottom Slab		Number of Spans 2	Number of Piers in Waterway 1						
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20px; text-align: center;">5</td> <td> Bents (1) Abut/PierWall (2) Web Wall (3) Columns (4) Shaft (5) Piles (6) Bracing (7) Foundation (8) Footing (9) Seal (1 0) Piles (11) </td> </tr> <tr> <td style="text-align: center;">T</td> <td> Scour (12) Scour Mitigat. (1 3) </td> </tr> <tr> <td style="text-align: center;">8</td> <td> Channel (14) Streambed (15) Drift (16) Flow (1 7) </td> </tr> </table>	5	Bents (1) Abut/PierWall (2) Web Wall (3) Columns (4) Shaft (5) Piles (6) Bracing (7) Foundation (8) Footing (9) Seal (1 0) Piles (11)	T	Scour (12) Scour Mitigat. (1 3)	8	Channel (14) Streambed (15) Drift (16) Flow (1 7)	<p>0 The 5th Avenue Bridge is inventoried from west to east. Abutments/wingwalls and pier walls are designated by numbers, and girders by a south to north lettering system. Underwater inspection of the Budd Inlet side of the dam began at 10:13 (PST) and ended at 14:01 (PST) on May 24, 2007, with respective waterline elevations of 6.5 and 8.0 feet. Underwater inspection of the Capitol Lake side began at 10:14 (PST) and ended at 11:00 (PST) on May 25, 2007.</p> <p>2 The majority of the concrete abutment elements exhibit only minor deterioration, including cracking and spalling. Observations include efflorescence (see Photograph 3) and infrequent instances of medium deterioration, including localized defects that do not significantly affect serviceability of the abutment element. The abutment elements include the integral wing walls from the Capitol Lake side (upstream) as well as the Budd Inlet side (downstream). The stoplog cutout on abutment 1 exhibited medium deterioration. Moderate corrosion cracking and spalling was noted at each corner of the cutout, extending from the high water mark to the top of the pier wall. Non-reinforcing steel is also visible in some of the spots along the corroded corners of the cutouts. The downstream wing walls exhibited scattered spalls on the interior sides that range up to 3 feet wide, as well as cracks ranging up to 4 feet long, with one instance of a partially opened corner spall approximately 15 feet long by 1 foot wide (see Photograph 1). The upstream wing walls are in good condition and no damage was reported.</p> <p>Similar to the abutment elements, the majority of the submerged pier wall length shows only minor deterioration, including minor cracking and spalling. Instances of spotted discoloration and efflorescence were observed above the waterline but do not affect strength or serviceability. Small areas of localized medium deterioration were observed on the walls, including delamination, spalling, and exposed steel with signs of corrosion. The stoplog cutouts show moderate to severe corrosion cracking and spalling on each corner, propagating from the high water mark to the top of the pier wall. The vertical corrosion cracks exhibit discoloration and non-reinforcing steel is visible along the corners, with rebar exposed near the tops of the cutouts. Both abutments and pier walls displayed occasional instances of severe spalling near the bottoms of the elements, with spall depths ranging in excess of 8 inches, exposing reinforcing steel. However, loss of section appears incidental and does</p>		
5	Bents (1) Abut/PierWall (2) Web Wall (3) Columns (4) Shaft (5) Piles (6) Bracing (7) Foundation (8) Footing (9) Seal (1 0) Piles (11)								
T	Scour (12) Scour Mitigat. (1 3)								
8	Channel (14) Streambed (15) Drift (16) Flow (1 7)								

not significantly affect strength or serviceability of the element or the bridge. The overall substructure, independent of the deck and superstructure, is in fair condition since all primary structural elements are sound but exhibit deterioration, cracks and spalls.

- 12 There is no significant local or general scour present at the bridge site. Movement of existing rock armorment appears unlikely. Bridge is over tidal water and previous scour evaluations were not found.
- 13 Divers inspected riprap on both Capitol Lake and Budd Inlet sides of the dam. The upstream side indicated uniform consistency in riprap near the ends of the wing walls, with gravel filling in the voids at those locations. The area of channel bottom between the upstream wing walls is lined with rock armorment that remains uniform in size and shape, ranging to excess of 5 feet wide and estimated between 2 and 3 tons.

The downstream side of the channel is lined with a concrete slab, and no scour was observed. Divers inspected the riprap lining beyond the downstream wing walls, which appeared to be generally uniform in size and shape. Along the downstream end of the bottom slab exists a ¼ inch steel sheet pile that protrudes up from the slab approximately 12 inches. The steel sheet pile was in good condition, exhibiting only minor corrosion typical of steel submerged in saltwater.

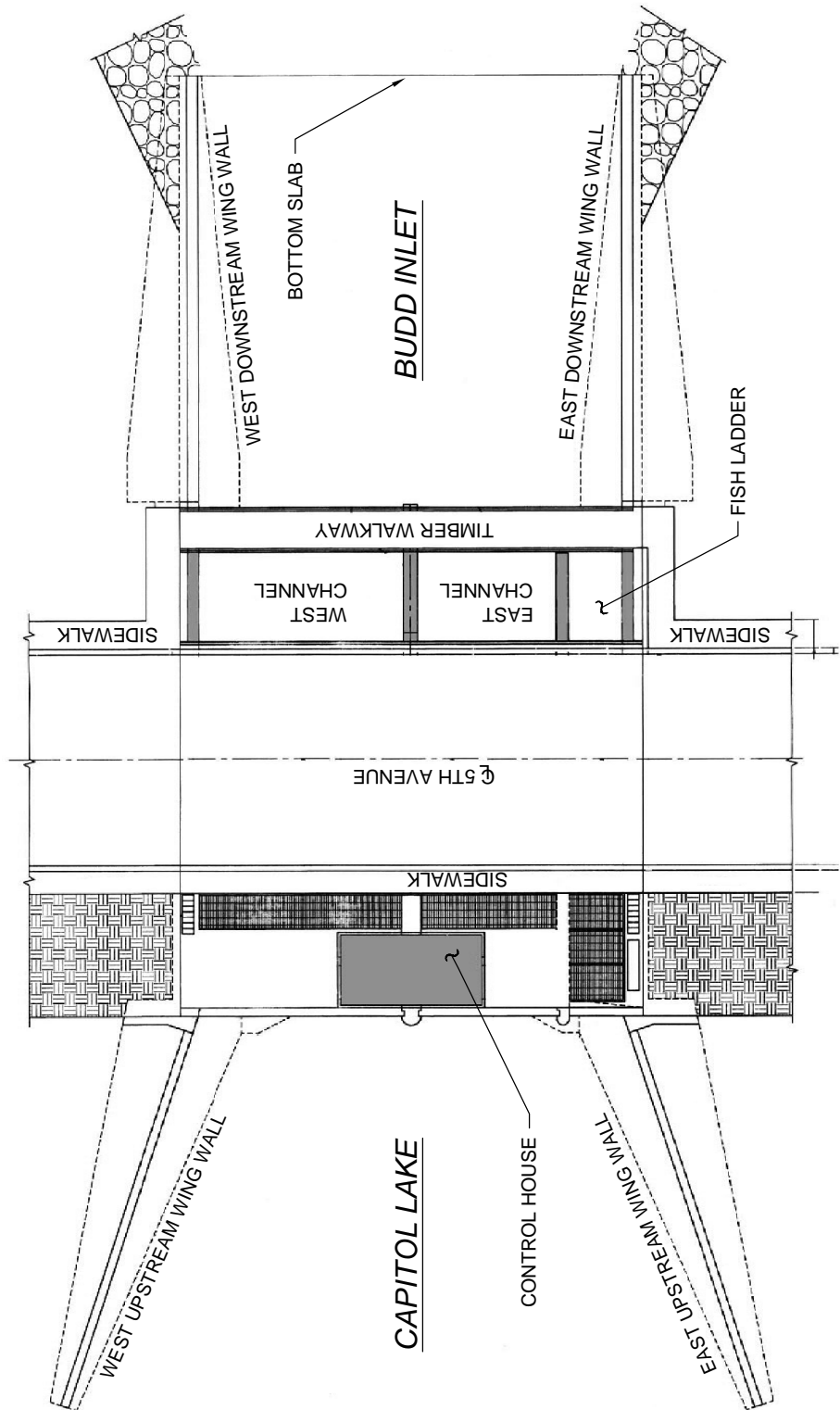
A few large gaps between rocks were noted at intermittent locations along the west shoreline up to approximately 50 feet beyond the end of the westerly downstream wing wall, suggesting possibility that some of the riprap has moved from its original placement.

- 14 The channel is stable, with little or no significant flow restrictions upstream or downstream of the radial arm gates, other than what was intended in its design.
- 15 The upstream side of the channel shows two distinct flow routes, characterized by rock-lined depressions extending in the north-south direction from the two gates.

The downstream channel bottom is defined by a concrete spillway divided at the south end by pier wall 2. There is an ogee located just downstream of each gate, consisting of a crest that serves as a bearing pad for the lower radial gate seals. Looking downstream, the ogees slope down gradually for approximately 20 feet, at which point the bottom slab becomes level for approximately 50 feet until reaching a sill, or wall approximately 6 foot high and 3 feet wide, located at the stoplog cutouts and serving as a bearing surface for any future stoplogs. Beyond the sill, a level concrete slab extends north as far as the ends of the downstream wing walls. The ogees exhibited no significant damage where accessible, although divers felt streams of water jetting through the lower gate seals at varying locations along each gate. Jet streams were also felt intermittently along the vertical seals of the gates (see Photograph 5). Large pieces of steel, concrete, other mechanical components and debris have unobtrusively accumulated around the centerline of each gate, immediately downstream of the sills. Minor and medium deterioration was observed at varying locations around the level bottom slabs, with cracks ranging up to several inches deep and over 10 feet long. Spalls in excess of 10 inches deep and several feet in diameter were also noted along the bottom slab, many of which were in areas of localized around the expansion joint located approximately 20 feet downstream of the stoplog cutouts. The majorities of the significant spalls and cracks are found on bottom slab between downstream wing walls.



- 16 Debris accumulated immediately downstream of sills (refer to note 15), due to a malfunction in the gate lifting mechanism which caused various mechanical and other components to fall into the spillway (personal communication with Larry Kessel on May 24, 2007). However, the debris accumulation is positioned such that flow is not restricted.
- 17 Flow is primarily regulated by the two radial arm gates and partially by weirs that compose the fish ladder located between wall 3 and abutment 4.



SCALE: (NTS)

Figure
1

PLAN VIEW

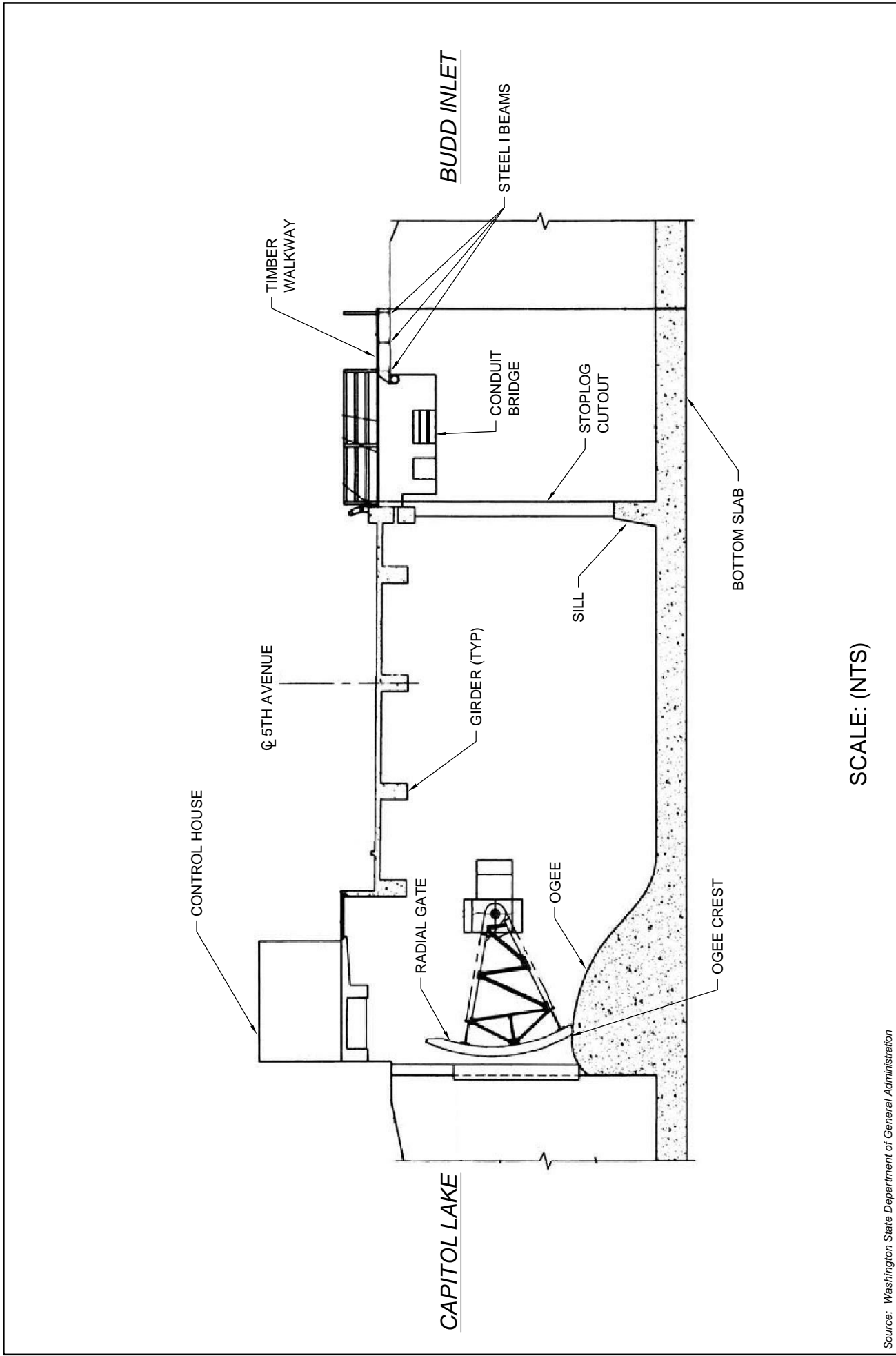
OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

Source: Washington State Department of General Administration

Moffatt & Nichol

Prepared by: Moffatt & Nichol

Date: June 22, 2007



SCALE: (NTS)

Source: Washington State Department of General Administration

Moffatt & Nichol

Prepared by: Moffatt & Nichol

Date: June 22, 2007

OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

WEST SECTION VIEW

Figure
2



CLOSED CORROSION SPALL

OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

EAST DOWNSTREAM WING WALL

Photograph
1

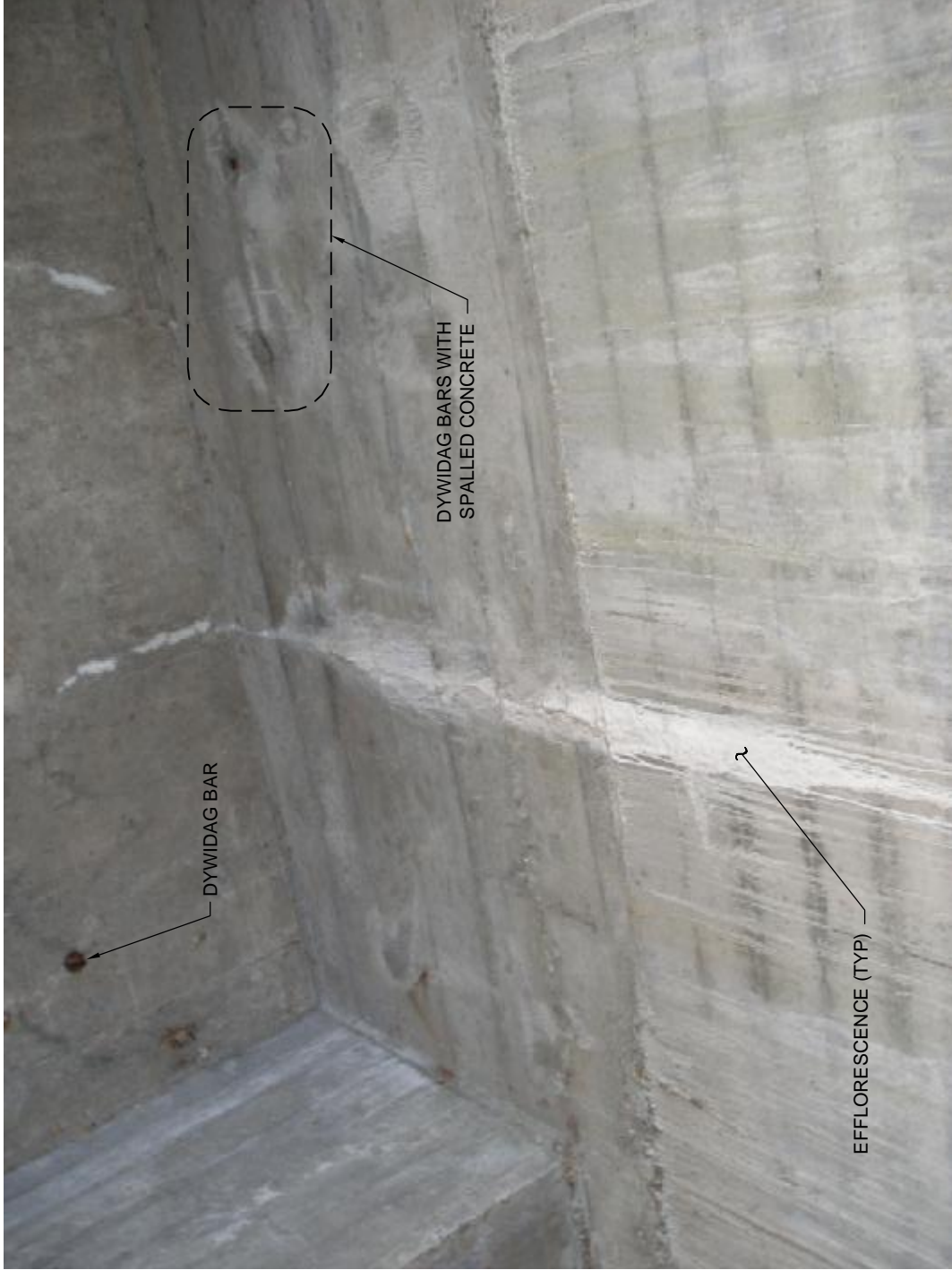


LOOKING NORTH FROM CAPITOL LAKE

OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

RADIAL ARM GATES

Photograph
2



EFFLORESCENCE AND DYWIDAG BARS

OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

WEST ABUTMENT (DOWNSTREAM)

Photograph
3



LOOKING SOUTH

OLYMPIA FIFTH AVENUE DAM
UNDERWATER INSPECTION

WEST RADIAL ARM GATE

Photograph
4



LOOKING SOUTH FROM BUDD INLET SIDE

APPENDIX B
Laboratory Report, Krazan & Associates, Inc.



Krazan & ASSOCIATES, INC.

GEOTECHNICAL ENGINEERING • ENVIRONMENTAL ENGINEERING
CONSTRUCTION TESTING & INSPECTION
FORENSIC INVESTIGATION

MOFFATT & NICHOL

JUL 01 2008

REC'D SEATTLE

KA No. 096-07260

Lab Report No. 1

Page 1 of 7

June 30, 2008

Susan Tonkin

MOFFATT & NICHOL

600 University Street, Ste 610

Seattle, Washington 98104

**RE: Concrete Laboratory Testing
Capitol Lake Dam Pile Cores Lab Testing
11715 North Creek Parkway South
Bothell, Washington**

Dear Ms. Tonkin:

In accordance with your request and authorization, we have performed laboratory tests for the above referenced project.

Laboratory testing was performed in general accordance with ASTM standards. The results of the laboratory tests are presented on the following pages. If you have any questions, or if we can be of further assistance, please do not hesitate to contact our office.

Respectfully submitted,
KRAZAN & ASSOCIATES, INC.


Corbett Mercer
Project Manager
Pacific Northwest Division

CM/lm

THEODORE P. PASTER, Ph.D.
Consultant
6244 Red Canyon Drive, Apt. B
Littleton, Colorado 80130
(303) 771-8219; e-mail: tedpaster@aol.com

June 27, 2008

Jeff Mercer
Krazan and Associates
11715 N. Creek Parkway S., Ste C106
Bothell WA 98011

**RE: Petrographic Analysis of Two Concrete Cores from Dam Project #07260,
According to ASTM C856-01:**

CONCLUSIONS

The concrete sampled is in very good condition and shows no deterioration.

There appears to be some fracturing caused by exterior forces and not from changes within the concrete itself. Minor anomalies of selected pertinent parameters in the concrete shown in **TABLE 1** can be explained by this fracturing.

There is no corrosion of the steel bars that are about 3.5 inches from the primary fracture or joint at the flat end of the cores.

Respectfully submitted:

**TABLE 1
SELECTED PHASES AND PARAMETERS IN 2 CONCRETE CORES
AND COMPARISON WITH NORMAL CONCRETE
DAM PROJECT; KRAZAN & ASSOCIATES**

Core KZ1:

Parameter	ts No:	a	c	b	avg a+c+b	Normal Concrete non-air-entrained
% air (adjusted)		0.6 ± 0.6	1.6 ± 0.9	2.1 ± 0.9	1.5 ± 0.5	2.0
Reactive CA / Total CA		0	0.09	0.14	0.09	0
Reactive FA / Total FA		0.23	0.09	0.1	0.13	no limit
% pp/% p		0.31	0.05	0.02	0.09	<0.15
%p /% FA		0.75	0.80	0.80	0.79	0.91
% Fractures		0.2	0.1	0.1	0.1	0

Core KZ2:

Parameter	ts No:	a	c	b	avg a+c+b	Normal Concrete non-air-entrained
% air (adjusted)		2.3 ± 1.0	1.7 ± 0.9	1.2 ± 0.7	1.6 ± 0.5	2.0
Reactive CA / Total CA		0.58	0.05	0.05	0.18	0
Reactive FA / Total FA		0.14	0.12	0.17	0.14	no limit
% pp/% p		0.06	0.08	0.09	0.08	<0.15
%p /% FA		1.24	1.01	0.91	1.04	0.91
% Fractures		0.3	0.2	0.3	0.2	0

Legend: FA = fine aggregate CA = coarse aggregate p = total paste
ts = thin section Reactive = possibly ASR pp = porous paste

INTRODUCTION AND CORE DESCRIPTIONS

Two concrete cores taken from a dam according to ASTM C856-01. The cores are from a concrete dam.

Macroscopic descriptions of the cores are as follows:

Core KZ1:

Labeled: 4", w 1
Girder F
5' AWL
5/31/07 @ 12:30 L

This core is 3 5/8" diameter x 3.5" long. Top (flat) surface has flat circular deposits of CaCO₃. Bottom surface is broken along reinforcement bar contact. There is no corrosion of rebar.

Core KZ2:

Labeled: 4", (w side)
Girder G 6" AWL
5/31/07 @ 15:30

Dimensions are 3 5/8" diameter x 4 1/4" long. Top flat surface has flat circular deposits of CaCO₃.

Both cores contain rounded gravel particles having dark rims about 2mm thick. These appear to be a weathering phenomenon from the deposit where the gravel was collected.

METHOD

The concrete was examined according to the recommendations of ASTM C856-01 entitled "Standard Practice for Petrographic Examination of Hardened Concrete". All thin sections are cut parallel to the cores' vertical axes and have been impregnated with blue epoxy to determine porosity and fracturing. Three thin sections were cut from each core. Thin section "a" includes a cross section of the flat surface. Section "b" is from the bottom of the core and section "c" is from the center of the core.

Fractures and air voids were studied. Point counting was performed on all sections at two grid spacings to determine the following phase percentages:

- Fine aggregate (FA) - <4.75mm to >0.075mm
- Paste (p)
- Dust (Clay + silt, 0.075mm)
- Air

The coarse aggregate (CA) content was not measured due to the limited sample size. Instead it is assumed to be 40% by volume that is common for most concrete mix designs.

RESULTS

Phase Percentages

The raw data of phase percentages from point counting are given in APPENDIX I.

TABLE 1 summarizes the pertinent petrographic parameters obtained in this analysis and compares them to a "normal" concrete with no entrained air. Except were noted the following descriptions refer to TABLE 1.

The parameters are normal except for the % reactive CA (Coarse Aggregate) and the % fractures.

Reactive CA

These gravel particles may ordinarily cause ASR (alkali-silica-reaction) but the high concentration of FA of the same material acts as a buffering agent to reduce the reactivity of the paste so there is no ASR evident in the cores.

Fractures

The fractures are relatively wide (A small fraction of a mm.) and appear to be related to some exterior cause rather than from changes within the concrete. There is some slight paste solution along the fractures but it's minimal. Some ettringite in voids near the flat surface of core 1 is normal and indicates some water movement through the concrete but this is minimal.

CaCO₃ on Flat End of Cores and Steel Corrosion

The deposition of CaCO₃ on these surfaces suggests that the circulating water in this area of the structure must be basic and its effect on the steel bars isn't corrosive.

If any corrosion is present it must be associated with relatively large fractures or joints where the water circulation is relatively fast and certainly faster than what has caused the effects seen in these cores.

June 27, 2008

**APPENDIX I
PHASE PERCENTAGES IN 2 CONCRETE CORES
DAM PROJECT; KRAZAN & ASSOCIATES**

CORE KZ1:
thin section No:

Phase	a		c		b		Avg (a+c+b)		
	cts	%	cts	%	cts	%	cts	%	±
Air	8	0.7	33	2.3	45	2.5	86	2.0	+ 0.5
Paste, normal	264	22.6	471	32.8	510	28.6	1245	28.4	
Paste, porous (pp)	97	8.3	27	1.9	11	0.6	135	3.1	+ 1.6
Paste, non-hydrated	7	0.6	15	1.0	14	0.8	36	0.8	
Fine Aggregate (FA)	392	33.5	602	42.0	621	34.8	1615	36.8	+ 1.7
(FA) Chert	67	5.7	44	3.1	50	2.8	161	3.7	+ 0.6
(FA) Volcanic glass	52	4.4	17	1.2	18	1.0	87	2.0	+ 0.5
Fractures	13	1.1	4	0.3	4	0.2	21	0.5	+ 0.2
Coarse Aggregate	270	23.1	222	15.5	512	28.7	1004	22.9	
Totals	1170	100.0	1435	100.0	1785	100.0	4390	100.0	

CORE KZ2:
thin section No:

Phase	a		c		b		Avg (a+c+b)		
	cts	%	cts	%	cts	%	cts	%	±
Air	41	3.0	41	2.7	29	1.6	111	2.5	+ 0.5
Paste, normal	461	33.6	576	37.4	538	28.8	1575	35.9	
Paste, porous (pp)	31	2.3	51	3.3	55	2.9	137	3.1	+ 1.6
Paste, non-hydrated	17	1.2	14	0.9	28	1.5	59	1.3	
Fine Aggregate (FA)	467	34.0	587	38.1	497	26.6	1551	35.3	+ 1.6
(FA) Chert	32	2.3	42	2.7	47	2.5	121	2.8	+ 0.5
(FA) Volcanic glass	47	3.4	38	2.5	52	2.8	137	3.1	+ 0.6
Fractures	5	0.4	4	0.3	7	0.4	16	0.4	+ 0.2
Coarse Aggregate	272	19.8	189	12.3	616	33.0	1077	24.5	
Totals	1373	100.0	1542	100.0	1869	100.0	4784	109.0	

Legend:

cts = counts

ts = thin section

p = total paste

FA = fine aggregate

pp = porous paste



June 13, 2008

Jeff Mercer
Krazan & Associates
11715 Northcreek Parkway South
Bothell, WA 98011

**RE: Analysis for Acid-Soluble Chloride in Concrete
Capital Dam Coring Samples
CASE Forensics Project No. 1315005**

Dear Mr. Mercer:

Pursuant to your request, CASE Forensics Corporation analyzed ten provided samples of pulverized concrete in accordance with ASTM Standard Test Method C1152 (*Acid Soluble Chloride in Mortar and Concrete*). The samples were reportedly collected from various locations on your Capital Dam Project. The analytical results are presented in Table 1 on the following page.

If you have any questions or comments regarding any element of our report, please contact me.

Respectfully Submitted:

A handwritten signature in black ink, appearing to read "Warren Harris".

Warren F. Harris
Senior Forensic Chemist
CASE Forensics Corporation

Reviewed By:

A handwritten signature in black ink, appearing to read "Daniel V. Joyce".

Daniel V. Joyce, PE
Principal Engineer
CASE Forensics Corporation



SEATTLE
23109 55TH AVE. W., MOUNTLAKE TERRACE, WA 98043
P 425.775.5550 F 425.775.0900

PORTLAND
4636 N. WILLIAMS AVE., PORTLAND, OR 97217-2828
P 503.736.1106 F 503.736.1051

DENVER
3545 S. PLATTE RIVER DR., UNIT M2, SHERIDAN, CO 80110
P 303.279.2768 F 303.279.3002

TABLE 1
ANALYTICAL RESULTS FOR CHLORIDE IN CONCRETE
CAPITAL DAM PROJECT

ASTM Standard Test Method C1152 (*Acid Soluble Chloride in Mortar and Concrete*)

Sample ID	Location	Chloride Percent
A	Upstream Wing Wall #4	0.020 %
B	W# 1 D2" 6' Awl	0.133 %
C	2" W3 Girder E 4' Awl	0.429 %
D	WW4 3' Awl at Center of West Face	0.377 %
E	2" W3 (West Side) Girder F/G, 4' Awl	0.285 %
F	W #1 DS Wing Wall 2" 6' Awl	0.319 %
G	2" W2 (West Side) 4' Awl, Girder G	0.088 %
H	Upstream Wing Wall #1	0.030 %
I	2" W@ (East Side) Girder C/D 5' Awl	0.314 %
J	PW #1 B/C 2" 6' Awl	0.423 %



APPENDIX C
Laboratory Report, Materials Service Life, LLC



CONCRETE CORES CHARACTERIZATION
Coast Guard – Capitol Lake Dam
Materials engineering report

Preliminary Report

July 2008

Project No. MSL07311

Prepared for:

Mike Hemphill
Moffatt & Nichol
710 Second Avenue, Suite 720
Seattle WA 98104
USA

Prepared by:

Materials Service Life, LLC
1400 Boul. du Parc Technologique, Suite 203
Quebec QC G1P 4R7
Canada

TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	TRANSPORT PROPERTIES EVALUATION	1
	<i>2.1 Porosity</i>	<i>1</i>
	<i>2.2 Pore Solution Extraction</i>	<i>2</i>
	<i>2.3 Ionic Migration Tests</i>	<i>2</i>
3	CONCLUSION.....	3

LIMITED LIABILITY STATEMENT

THIS REPORT IS FOR THE EXCLUSIVE USE OF M.S.L.'S CLIENT AND IS PROVIDED ON AN "AS IS" BASIS WITH NO WARRANTIES, IMPLIED OR EXPRESSED, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, WITH RESPECT TO THE SERVICES PROVIDED. M.S.L. ASSUMES NO LIABILITY TO ANY PARTY FOR ANY LOSS, EXPENSE, OR DAMAGE OCCASIONED BY THE USE OF THE REPORT. ONLY THE CLIENT IS AUTHORIZED TO COPY OR DISTRIBUTE THIS REPORT AND THEN ONLY IN ITS ENTIRETY. THE REPORT'S ANALYSIS, RESULTS, AND RECOMMENDATIONS REFLECT THE CONDITION OF THE SITES TESTED EXCLUSIVELY, AND MAY NOT BE REPRESENTATIVE OF ALL LOCATIONS THROUGHOUT A TESTED STRUCTURE. THE REPORT'S OBSERVATIONS AND TEST RESULTS ARE RELEVANT ONLY TO THE SAMPLES TESTED AND ARE BASED ON IDENTICAL TESTING CONDITIONS. FURTHERMORE, THIS REPORT IS INTENDED FOR THE USE OF INDIVIDUALS WHO ARE COMPETENT TO EVALUATE THE SIGNIFICANCE AND LIMITATIONS OF ITS CONTENT AND RECOMMENDATIONS AND WHO ACCEPT RESPONSIBILITY FOR THE APPLICATION OF THE MATERIAL IT CONTAINS.

THE STADIUM[®] MODEL IS A HELPFUL TOOL TO PREDICT THE FUTURE CONDITIONS OF CONCRETE MATERIALS. HOWEVER, ALL DURABILITY-MODELING PARAMETERS HAVE A STATISTICAL RANGE OF ACCEPTABLE RESULTS. THE MODELING IN THIS REPORT USES MEAN LABORATORY - OR FIELD-DETERMINED SINGLE VALUES AS INPUT PARAMETERS. THIS PROVIDES A SINGLE RESULT, WHICH PROVIDES A SIMPLE ANALYSIS EVALUATING CORROSION PROTECTION OPTIONS. PREVIOUS CONDITIONS ARE ASSUMED TO CARRY FORWARD IN THE PREDICTION MODEL; THERE ARE NO ASSURANCES THAT THE STRUCTURE WILL BE EXPOSED TO A SIMILAR ENVIRONMENT AS IN THE PAST.

ALL ANALYSES IN THIS REPORT ARE BASED STRICTLY ON THE CORROSION PROTECTION AND CONDITION OF THE REINFORCED CONCRETE MATERIALS. THE CONDITION APPRAISAL AND ANALYSIS BY NO MEANS CONSTITUTE A STRUCTURAL ENGINEERING CONDITION APPRAISAL OR ANALYSIS. ANY AND ALL RECOMMENDATIONS PRESENTED IN THIS REPORT SHOULD BE VERIFIED AND VALIDATED BY A COMPETENT STRUCTURAL ENGINEER.

1 Introduction

Materials Service Life, LLC was hired by **Moffatt & Nichol** to characterize concrete cores extracted from the Capitol Lake Dam. Two 3¾-in. diameter cores were sent to MSL’s laboratory for analysis.

The cores were received on May 20, 2008. Transport properties tests (porosity and ionic diffusion coefficient) were performed on the concrete cores. The following activities were performed during this mandate:

- Ionic migration test – modified ASTM C1202 *Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration*
- Pore solution extraction
- Porosity of concrete – ASTM C642 *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*

2 Transport properties evaluation

The transport properties were evaluated on the concrete from the Capitol Lake Dam located in Olympia, WA. Table 1 presents the cores received.

Table 1 - Identification of cores as received

Client ID	Location
Core K	4’’, W1, Girder E 6’ AWC
Core N	4’’, W3, Girder E 4’ AWC

2.1 Porosity

Porosity measurements were performed in accordance with ASTM C642 – *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*. In addition to provide information on the quality of in-place concrete, porosity values were used as input parameters in STADIUM®-IDC to determine ionic diffusion coefficients. Porosity corresponds to the total volume of voids that can be saturated with water. Porosity tests were performed just after ionic migration tests on the same specimens. Results are summarized in Table 2.

As can be seen in Table 2, porosity results are 7.6% and 9.9%. Good quality normal-weight concrete (a 0.45 water-binder ratio and normal weight aggregates produced in the laboratory) exhibits porosity values around 12%. Low porosity values would be expected

to yield low diffusion coefficients. The absorption ranges from 3.1% and 3.9%, which correlates with the porosity results.

Table 2 – Absorption and Porosity Results

Location	Absorption %	Porosity %
Core K	3.9	9.9
Core N	3.1	7.6

2.2 Pore Solution Extraction

Data on the pore solution chemistry of concrete is needed to determine ionic diffusion coefficients. Concrete specimen was taken from the bottom of core K (more than 2 inches from the exposed surface). This companion specimen was saturated in a 0.3 M NaOH solution at the same time than the migration test specimens. After saturation, it was broken into small pieces, placed in a cell and crushed at a pressure of approximately 72,500 psi (500 MPa). Pore solution analyses were carried out shortly after extraction by using atomic absorption analyzer and ion chromatography as well as a pH titrator to obtain the contents of the main ionic species in the pore solution (i.e. OH⁻, Cl⁻, Na⁺, K⁺, Ca²⁺, and SO₄²⁻). Chloride was found in the pore solutions. This suggests that the concrete is contaminated from chlorides.

2.3 Ionic Migration Tests

Ionic migration tests were performed to characterize the ionic diffusion properties of the concrete cores.

The test used is a modified (and improved) version of ASTM C1202 – *Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration*. Ion transport, through a saturated concrete specimen, was accelerated by applying an electrical potential to the test cell. During testing, the current passing through the sample was measured. STADIUM[®]-IDC, a specialized version of STADIUM[®], was used to analyze the migration test results and evaluate the ionic diffusion coefficients for each location. The selected cores and their respective results are presented in Table 3.

A high ionic diffusion coefficient means that contaminants, such as chlorides, diffuse faster through concrete. The diffusion coefficients measured ranges from $1.1 \times 10^{-11} \text{ m}^2/\text{s}$ to $0.6 \times 10^{-11} \text{ m}^2/\text{s}$. From these results, the concrete is considered to have an ionic diffusion coefficient in the range of a good quality concrete prepared in laboratory and having a water/binder ratio of 0.45 (values from $1 \text{ to } 2 \times 10^{-11} \text{ m}^2/\text{s}$). Both results correlate with the

porosity results presented in Table 2. The lower ionic diffusion coefficient corresponds with the lowest porosity.

Table 3 – Ionic Diffusion Coefficients

Location	Ionic Diffusion Coefficient ($10^{-11} \text{ m}^2/\text{s}$)
Core K	1.1
Core N	0.6

3 Conclusion

Materials Service Life, LLC was mandated to evaluate the transport properties on concrete cores extracted from the Capitol Lake Dam. Results show differences between the two tested cores. Higher porosity value yielded higher diffusion coefficient. Overall, all concrete properties correspond to a good quality concrete. Chlorides were found in the pore solution, which suggests that the concrete is contaminated from an external source of chlorides.



Xavier Willem, Ph.D.



Eric Ouellet, P. Eng., M.Sc.
Director of Operations

APPENDIX D

Tide Gates Machinery and Controls Assessment, Lund Engineering, Inc.



LUND ENGINEERING, INC.

12600-A Interurban Avenue South Tukwila, WA 98168-3314
(206) 973-1025 (206) 973-1028 FAX

www.lundeng.com

FIFTH AVENUE DAM CAPITOL LAKE TIDE GATES MACHINERY AND CONTROLS ASSESSMENT

June 30, 2007

Prepared by: Daniel Schade, Gregg Moore
Lund Engineering, Inc.
For Moffatt & Nichol

BACKGROUND

The Capitol Lake Tide Gates serve as a level control means for Capitol Lake and helps to prevent flooding of downtown Olympia. The two radial gates operate within an earthen dam separating Budd Inlet and the north Basin of Capitol Lake. The dam also prevents the incursion of Puget Sound salt water into the fresh water lake.

Original construction of the dam was completed in 1952. Major rehabilitation projects took place in 1987 and 1995. On going preventive maintenance and repair work has been augmented in recent years with a complete overhaul of the control system.

The 24 foot wide east and 36 foot wide west gates are mechanically operated using independent wire rope hoisting systems. The hoists are driven using electric motors through a combination of gear reducer, roller chain, and open gears. Two wire ropes are played out from two rope drums connected through a common drive shaft. The west radial gate has a hydraulically operated back-up system. The tide gate mechanical and control systems are contained within the machinery house located over the top of the two gates on the dam. Stop logs can be inserted upstream of the dam to dewater the gates; however, there are no provisions for dewatering on the Puget Sound side of the gates. All electrical and mechanical tide gate components are inspected and maintained by the State.

SITE-VISIT WITH DAM OPERATOR

On Tuesday May 29th the Lund Engineering team arrived at the dam and met with Larry Kessel, Washington State Dept. of General Administration, to inspect the dam and discuss tide gate operations. Mr. Kessel has been responsible for operating the tide gates for approximately eight years. The dam tide gates are continuously monitored and controlled by the METASYS system. This system measures the lake level from two points near the opening of the east and west gates. A third sensor measures the Budd Inlet tide level downstream from the gates. The METASYS system compares the level in the Capitol Lake to that of Puget Sound and if required opens the east tide gate allowing the lake water to flow into Puget Sound. The outflow continues until the lake level falls into the programmed acceptable range. If the rate of lowering the lake level is deemed to be too slow the METASYS system will open the west gate to increase the outflow. The dam operator stated that he has never witnessed the system automatically opening the second gate. The gates are opened approximately two to three times a day in the summer and three to four times per day in the rainy months. The dam operators frequently open the gates manually in a preemptive manner when they anticipate an 'event' (possible flooding conditions) and the Puget Sound tide condition allows. The timing of lake lowering is critical and often the operator's consider the METASYS system control of the gates to be too slow.

Several years ago two of the hoisting lines broke and the gate became jammed. The accident was the result of one of the control system rotary switches failing to stop the rising gate and the gate crashed into concrete structure. When the gate impacted the structure and the wire ropes failed. The maintenance department has installed a back-up limit switch on the west gate. If the rotary switch fails the back-up limit will stop the gate before impact. Presently the east side gate does not have a limit switch.

The fish gate is a manually controlled and operated vertical weir gate. For most of the year this gate remains open. There is a diesel generator set and automatic transfer switch located in the dam machinery room. The generator provides back-up electrical power in case of an outage.

INSPECTION OF MACHINERY AND CONTROLS

Tide Gates Machinery

Typical operational parameters for the tide gate machinery are as follows: 2 to 4 opening/closing cycles per day, 15 to 20 minute operating times per cycle, nearly steady load (no shock loads) with adequate time for the machinery to cool off between cycles. During our inspection we did not attempt to load test any system or disassemble any components (other than opening access panels) to gain better access for observation. All observations were made from the machinery house or the gate catwalk.

The radial gates are lifted by four plastic coated wire ropes, one pair at each end of the gate. The ropes are connected to the gates using an "equalizer" plate and pin. The equalizer ensures that the two ropes share the load equally. The ropes, rope terminators, and equalizer mounting hardware appear to have been recently replaced and are in very good condition. The ropes are stored on two grooved steel drums connected through a common shaft (see figure 1). The ropes are wound on the drums in a neat orderly fashion. We did not observe any evidence of damage to the wire ropes. Pillow block bearing assemblies support the shaft. All the shaft bearings are fitted with grease couplings for re-lubrication. For both gates the shaft bearings and drive shaft show the onset of corrosion. On the west gate a noisy bearing was identified at the far west end (see figure 2).

The wire rope drums are connected to an open spur gear set which is driven by a chain and sprocket arrangement. Based upon our limited inspection the gears for both gates appear to be in good condition. There is an absence of visible damage to the gear teeth (cracking or surface damage) or any excessive tooth wear. Gear alignment would appear to be good due to the absence of any appreciable rounding of the gear teeth or evidence of undercutting. The drive chain is well lubricated and tensioned.

The drive sprockets are connected to a cone type gear reducer with a 625 to 1 gear ratio. The gear reducers do not exhibit any alarming noises or show any signs of leaking oil from the shaft seals. The east and west gate drive mechanisms still have their original gear reducers (see figure 3).

Each gate has a 3 horsepower electric motor as the prime mover. The motors are connected to the gear reducers through flexible shaft couplings. The motor for the west gate appears to be the original. Spring set motor brakes hold the gate load when the gates are in their open position. There are rotary limit switches connected to the large sprocket/pinion gear shaft. The switches are functioning but appear to be very old.

Tide Gate Controls

The dam tide gates are continuously monitored and controlled by a Johnson Controls METASYS control system (see figure 4). The METASYS control receives analog signals from sensors that measure the fresh water lake level from two points near the opening of the east and west gates, and from a third sensor which measures the salt water Budd Inlet tide level downstream from the discharge gates. The METASYS program is designed to monitor the level in Capitol Lake and that of Puget Sound. If the lake level is too high and is above that of Puget Sound, the system opens the east tide gate until the lake level falls into the acceptable range. If the rate at which the lake level is dropping is considered to be too slow, the METASYS controls will open the west gate to increase the discharge rate. When the water level in Puget Sound nears or exceeds that of Capitol Lake, the METASYS closes the east and west tide gates.

Additionally, the METASYS can be remotely commanded via the local area network (LAN) from the capitol campus power house, to raise or lower the lake level by opening or closing either or both gates. These types of operations usually occur when a drawdown of the lake is required due to a predicted future event. The LAN also allows users to view, through the METASYS controller, the operational status of the gates and the various water

levels. This information is also available locally at the control house through the METASYS operator station (see figure 5).

The METASYS controls the actual operation of the tide gates by energizing the appropriate motor controller located in the Motor Control Center (MCC) to operate an electric motor to open and close the chosen gate. The METASYS monitors the position of each gate through a signal from a potentiometer that is mechanically connected to the gate by a rotating shaft. A rotary limit switch is also coupled to the shaft and is designed to act as an End Of Travel (EOT) limit, thereby preventing the gates and gearing from being overdriven into the mechanical stop and causing a wire rope failure (see figure 6). As mentioned earlier, as a result of a possible switch failure, an additional limit switch has been installed to backup the rotary limit switch for the west gate (see figure 7). A switch has been purchased, but not yet installed, for similar application on the east gate.

Distribution Panel and Motor Control Center (MCC)

The distribution panel and motor control center occupy a free-standing multi-compartment two section enclosure. The right hand section houses the power distribution equipment and the automatic transfer switch (ATS) used to operate on generated power when the utility power is interrupted. The left hand section is the Motor Control Center (MCC) and houses the circuit breakers and motor controllers required for gate operation (see figure 8). Overall the enclosure appears to be in good condition, although some corrosion is evident at the bottom.

Distribution Panel (Right Section): The service entrance, lighting panel, and Automatic Transfer Switch, although somewhat dated, appear to be in good operating order. There is dust buildup on some of the components, but this does not appear to be enough for concern at the voltages used in this compartment. Continued operation of this equipment through the next decade should require only good preventive maintenance.

Motor Control Center (Left Section): The multi-compartmented motor control center houses all the circuit breakers and motor controllers for the three gate motors and the emergency hydraulic power unit pump motor. Again, the controllers and circuit breakers are somewhat dated, all are dusty, but appear to be in good operating condition. No buzzing of the contactor armatures was detected during the times they were energized, such as would occur if the armatures had been hammered excessively or if dirt and/or iron filings had accumulated. Continued good preventive maintenance should keep this equipment reliable for the next ten years or more.

West Gate Motor: The West Tide Gate motor and brake combination appears to be part of the original installation and therefore is about 60 years old. Its operation appears to be satisfactory although testing the windings might prove otherwise. We feel this motor is past its useful and reliable life of about 50 years and is overdue for replacement.

East Gate Motor: The original East Tide Gate motor has been replaced with the one currently in use. This motor and brake combination is a modern design (relative to the original) and is about 20 years old. It appears to be operating satisfactorily and should continue for the next thirty years or so.

Standby Hydraulic System

The west gate features a hydraulically operated gate back-up system in the event of a failure to the primary wire rope hoist system. The standby system consists of two large hydraulic cylinders with wire rope sheaves attached to the cylinder rods. Normally the system is not attached to the radial gates. This system requires divers to attach the ropes to the gates. Two hydraulic cylinders can then lift the west gate open. The hydraulic cylinders

are controlled via a solenoid operated directional valve located within the machinery room. A direct coupled pump is mounted to a 7 ½ horsepower electric motor. The hydraulic system utilizes biodegradable fluid.

All elements of the standby hydraulic system appear to be in good condition. The hydraulic cylinders are judged to be in very good condition and may have been replaced or rebuilt recently. We could not get access to the hydraulic reservoir tank to check the inside for corrosion. The location of the hydraulic reservoir is in the general area of the hoist open gears (see figure 9). The gates and water are directly below this area. In order to address environmental concerns related to hydraulic fluid spill the reservoir should be fitted with a drip pan or incorporate spill containment provisions. Additionally, the reservoir mounting arrangement appears to be inadequate and not in line with industry standards. All of the hoses and hydraulic fittings appear to be free from any leaks. The emergency gate lift Hydraulic Power Unit (HPU) is controlled by the operator through a pendant on a portable cord. The control system operates satisfactorily.

Hydraulic Power Unit Pump Motor: The HPU pump motor is of modern design, age unknown. It appears to be operating satisfactorily.

Fish Gate

The fish gate is located at the east end of the tide gates. The gate mechanical components appear to be in fair to good condition although quite old.

Vacuum Pump for Siphon System

The siphon system was added to the dam in 1987 to add oxygenated water to the lake bottom. The vacuum pump serves to augment the induced siphoning effect of the pipe and the tide. On the day we visited the dam the vacuum pump did not appear to be operational.

Siphon System Controls

The control system uses a conventional vacuum switch to stop and start the vacuum pump controller. The control system appears to be in good condition and should remain so with continued preventive maintenance. At the time of the inspection the vacuum pump was not operational.

Generator Set

The Onan 15kW back-up generator set is connected to the gate motor power system through the ATS located in the Distribution Panel section. The generator is clean and free of fuel or lubrication leaks. We were told the generator receives periodic maintenance and is tested under load on a regular interval. With less than 200 hours on the generator, the overall condition is good to very good.

Capitol Lake Level Controls (METASYS)

The Johnson Controls METASYS computer based control system was originally installed in the mid 1990s and recently had a software and hardware upgrade, although some legacy hardware is still in service. The system gathers its Capitol Lake and Puget Sound level data from various sensors located at the lake, and the gate position data from potentiometers connected to the gate gear train. The EOT limit switches are also input into the system from a pair of very old, but still functional, G.E rotary limit switches. A personal computer is linked

to the METASYS controller through a local Ethernet connection and acts as the man-machine interface (MMI) (see figure 4). The METASYS controller and the MMI are connected to the Capitol campus LAN through an optical link.

Manual operation of the gates is achieved by use of the gate control operator devices (push buttons, selector switches, etc.) located on the MCC front panels. Gate control is also available thru the MMI. When we first arrived for our inspection, the MMI would not connect with the METASYS and allow us to view current data. A technician was called and was able to establish the connection by entering the proper Ethernet addresses. At that time, the control and trend gathering capabilities of the MMI were explained.

Overall, the control system hardware and executive system software appear state of the art, and quite capable of controlling the lake level with the current data sensors. The operating system program and algorithms are apparently proprietary information and were not made available for examination, however based on the data gathered from a trend report; the system seems to work fairly well.

RECOMMENDATIONS

The tide gate machinery is generally in good operational condition and appears to be receiving adequate preventative maintenance. There were no significant corrosion concerns identified with the machinery at this point in time. The hoisting wire ropes should be inspected on a 6 month interval by a qualified technician experienced with hoisting equipment. Wire rope damage can be difficult to detect and inspection is further complicated by the rope plastic coating. The gearing and chain drive equipment should provide years of reliable service with periodic lubrication. Due to the age of the machinery we recommend inspection gears, sprockets, chain, and machinery shaft alignment on a 4 month interval. The shafts should be realignment if required. Shaft miss-alignment is a major contributor to premature bearing failure. The noisy shaft bearing on the west gate should be replaced immediately.

The east and west gate drive mechanisms still have their original gear reducers. Based on an estimated average of 2.5 opening/closing cycles per day, a 15 minute operation time per cycle and covering a 55 year period, these gear reducers have an estimated 25,000 hours of service. It is our opinion that the gear reducers are beginning to reach the limit of normal operating life for equipment of this type. Despite an absence of gear reducer damage we recommend a through inspection of both units. The reducers lubricating oil should be sampled and analyzed by a lab to possibly identify the presence of metal particles or other containments. We recommend consideration given to preemptively replacing the gear reducers based upon their age. The motor brakes on both gate motors should be inspected for wear on a 4 month interval.

The shaft couplings connecting the gate electric motors to the gear reducers should have guards installed to be in compliance with OSHA 1917.151 for rotating machinery. The guards can be designed to be easily removed for maintenance or inspection.

The standby hydraulic system should be tested twice per year. The test should include cycling the hydraulic cylinders to lubricate the seals and testing the hydraulic fluid. The hoses and hose fittings should be thoroughly inspected.

Consideration should be given to replacing the tide gate rotary type limit switches and position potentiometers with new. We recommend simplifying the switch and potentiometer drive design to improve adjustability and ease of calibration.

From our discussions with dam operator and the other technicians, we learned that they suspect a command, opening the gate from the power house, may have overridden the rotary limit switch EOT function and was the

actual cause of the wire rope breaking and the east gate being damaged. As a result of this accident the second switch has been added to the West Gate to directly break the connection to the controller coil. If the technician's suspicions are true, it is imperative that a limit switch be added to the East Gate to detect the full up position. This switch would serve as a back-up to the rotary switch currently used and will be similar to the arrangement already used on the West Gate. This type of backup is a very common practice on wire rope systems.

During our discussions with the campus technicians it became apparent that they distrust the METASYS programmed response to events that upset the level of the lake. For instance we were told that the east gate is programmed to be the first to respond to an event that raises the lake level, and then if (after some appropriate response time) the rate of level change is too slow, the west gate will open. Upon examination of data made available to us, the METASYS control command to open the west gate was always preempted by the operator's command to do so, and none could remember the west gate opening without an operator's command. This raises the question: 'Is the Operator's intuition more correct than the METASYS program,' i.e., is the METASYS programmed response to slow? Our recommendation is then to provide an on-site simulation and training exercise conducted by the system vendor, using the existing METASYS controls. Current loop signal generators can be inserted in the 4-20mA current loops to simulate the level conditions and the METASYS system's programmed responses can be monitored for correctness. If programming or algorithm errors exist, they can be identified and addressed, and the simulation run again until all parties trust the control system. We also recommend that, as part of the simulation, the METASYS system's response to various sensor failures, particularly level sensors, be examined for appropriateness.

We learned that when the recent METASYS retrofit occurred, the analog meters that displayed the water levels and gate positions were also removed. We feel this was not a good decision because it removed devices that show the relationships between the water levels and the machinery in real time. When we arrived for the inspection, the METASYS operator panel (MMI) was not communicating with the METASYS controller, and as a result there was no way for the operator to see the actual operating position of the machinery and the water levels, without physically going out to look at the tide gates and the graduation marks for water level. We recommend that the analog meters be reinstalled.

We also recommend the cabling and conduit runs to the lake and sound level sensors be examined for corrosion and be replaced or repaired if their integrity is damaged. Since the level transducers are in direct contact with the water, they are the most probable control system devices to fail in the near future. We recommend that, if it's not already the case, spare level sensors be kept for when these fail.

Additionally, due to accumulation of the dust observed, we recommend a thorough cleaning of the distribution and control components, cleaning and adjusting controller contacts, tightening bus, circuit breaker, and terminal connections, and lubricating where required. The control components should be vacuumed and wiped, not blown, clean. A good cleaning should be scheduled for every 2-3 years. Electrical contacts should be inspected for pitting and arc chutes examined for residual material from arc splashing on a yearly basis, replacing as necessary. Lubrication should occur during the contact inspection.

SUMMARY

Based upon our brief inspection of the tide gates our assessment of the machinery and control system is generally most favorable. Although some of the equipment is quite old the equipment is well maintained and in good working condition with an absence of significant deterioration. With the exception of a noisy bearing and the addition of a backup EOT limit switch on the East Gate, we did not identify any component or system that is in critical need of attention. The pillow block shaft bearing on the west gate should be replaced immediately.

To ensure complete OSHA compliance machinery guards should be installed over the gear reducer shaft couplings. We recommend careful consideration be given to either moving the hydraulic reservoir or improving the mounting arrangement with a drip pan or sump to catch potential leaks.

The balance of our remaining recommendations would be classified as design improvements intended to enhance reliability or extend the service life of the system. With continued periodic maintenance and regular comprehensive inspection of some of the older components, the tide gate machinery/controls should provide a decade or more of reliable operation. It is our opinion that a major portion of the tide gate machinery and controls will not continue to function reliably past the next ten years without replacement of major components. Annual maintenance costs will tend to increase as the machinery gets older. Control component parts will become more difficult to locate, resulting in replacement rather than repair. Total replacement of the entire system will probably be required in 20 to 40 years time. An estimate of future tide gate replacement cost is beyond the scope of this report; however, based on current component prices a rough order of magnitude cost for this rebuild would be approximately \$838,000 (see figure 10). This cost is pure construction cost, with no contingency or below-the-line costs, and is in present (2007) dollars.



Figure 1
East Gate Drum and Bull Gear



Figure 2
West Gate Pillow Block Bearing



Figure 3
West Gate Motor & Reducer

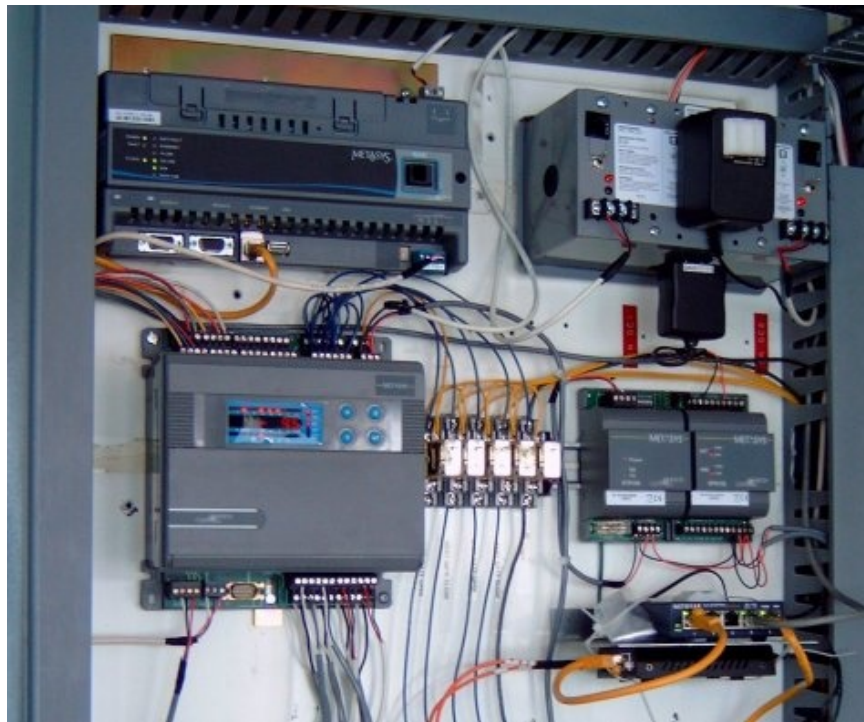


Figure 4
METASYS Controller



Figure 5
METASYS Operator Station (MMI)

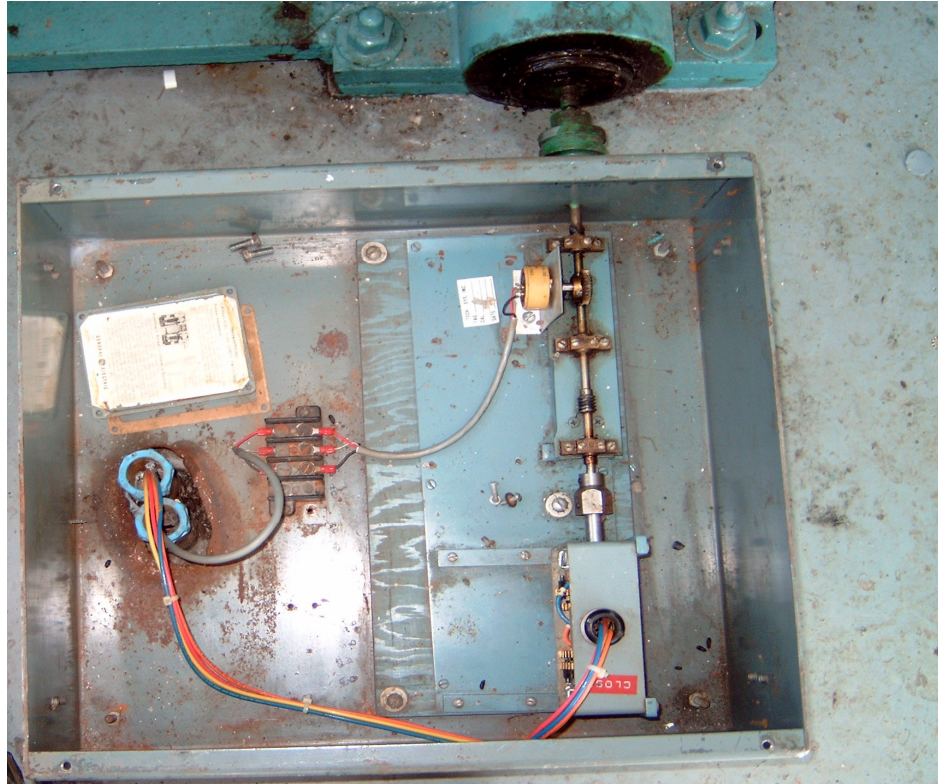


Figure 6
East Gate End of Travel Switch



Figure 7
West Gate Back-Up Limit Switch



Figure 8
Power Distribution Section (Right)
Motor Control Center – with compartments opened (Left)



Figure 9
Hydraulic Reservoir

CAPITOL LAKE TIDE GATE
REPLACEMENT COST ESTIMATE

Tide Gate Machinery	\$285,000
Fish Gate and other Machinery	\$87,000
Electrical Power Distribution	\$90,000
Electrical Controls	\$125,000
Installation/Testing Labor	\$135,000
Overhead	\$40,000
Mobilization	\$76,000
Total	\$838,000

This is a good faith estimate of probable cost based upon current estimated cost of similar equipment. This estimate should does not represent actual future replacement cost.

Figure 10

APPENDIX E
Manufacturer Brochures

SikaRepair® 223

One component, early strength gaining, cementitious patching material

Description	SikaRepair 223 is a one-component, early strength gaining, cementitious, patching material for vertical and overhead repair of concrete.
Where to Use	<ul style="list-style-type: none"> ■ On grade, above, and below grade on concrete and mortar. ■ As a repair material for vertical and overhead concrete surfaces.
Advantages	<ul style="list-style-type: none"> ■ Easy-to-use. ■ Suitable for exterior and interior applications. ■ Easily applied to clean, sound substrate. ■ High early strengths. ■ Increased abrasion resistance. ■ Increased freeze/thaw resistance. ■ Not a vapor barrier. ■ Not flammable.
Coverage	Approximately 0.41 cu. ft.
Packaging	SikaRepair 223 - 50 lb. multi-wall bag. SikaLatex R - 1 gal. plastic jug; 4/carton, 5 gal. pails

Typical Data (Material and curing conditions @ 73°F (23°C) and 50% R.H.)

Shelf Life	One year in original, unopened bags.	
Storage Conditions	Store dry at 40°-95°F (4°-35°C). Condition material to 65°-75°F before using.	
Color	Concrete gray	
Mixing Ratio	3/4 gal. to 1 gal. of liquid per 50 lb. bag	
Application Time	Approximately 15 min. after adding powder to Latex or Latex R. Application time is dependent on temperature and relative humidity.	
Finishing Time	20 to 60 min after combining powder and liquid: depends on temperature, relative humidity, and type of finish desired.	
Flexural Strength (ASTM C-293)		with undiluted Latex R
28 days	850 psi (5.9 MPa)	1,200 psi (8.2 MPa)
Splitting Tensile Strength (ASTM C-496)		
28 days	550 psi (3.8 MPa)	700 psi (4.8 MPa)
Bond Strength* (ASTM C-882 modified)		
28 days	1,800 psi (12.4 MPa)	2,000 psi (13.8 MPa)
Compressive Strength (ASTM C-109)		
1 day	3,000 psi (20.7 MPa)	3,300 psi (22.8 MPa)
7 days	6,000 psi (41.4 MPa)	6,200 psi (42.8 MPa)
28 days	7,000 psi (48.3 MPa)	7,500 psi (51.7 MPa)

*Mortar scrubbed into substrate

How to Use

Surface Preparation - Remove all deteriorated concrete, dirt, oil, grease, and all bond-inhibiting materials from surface. Be sure repair area is not less than 1/4 inch in depth. Preparation work should be done by scabbler or other appropriate mechanical means to obtain an exposed aggregate surface with a minimum surface profile of ±1/8 inch (CSP-6). Saturate surface with clean water. Substrate should be saturated surface dry (SSD) with no standing water during application.

Priming For priming of reinforcing steel use Sika Armatex 110 EpoCem (consult Technical Data Sheet).

Concrete Substrate: Prime the prepared substrate with a brush or sprayed applied coat of Sika Armatex 110 EpoCem (consult Technical Data Sheet). Alternately, a scrub coat of Sika Repair 223 can be applied prior to placement of the mortar. The repair mortar has to be applied into the wet scrub coat before it dries.



Mixing	<p>With water: Wet down all tools and mixer to be used. Add approximately 3/4 gal. of water to mixing vessel. Slowly add 1 bag of SikaRepair 223 while continuing to mix. Mechanically mix with a low-speed drill (400-600 rpm) and SikaTop Gel paddle. 1/4 gal. of water may be added to achieve desired consistency. Do not overwater. Maintain a mix temperature of 65°-75°F for maximum performance by using hot or cold water as needed.</p> <p>With Latex R: Pour 3/4 gallon of SikaLatex R into the mixing container. Slowly add powder while continuing to mix mechanically as above. Add remaining SikaLatex R (up to 1/4 gal.) to adjust the desired consistency.</p> <p>note: SikaLatex R must be protected from freezing. If frozen, discard.</p> <p>With diluted Latex R: Sika Latex R may be diluted up to 5:1 (water:Sika Latex R) for projects requiring minimal polymer-modification. Pour 3/4 gallon of the mixture into the mixing container. Slowly add powder and mix as above. Add remaining diluted SikaLatex R (up to 1/4 gal.) to adjust the desired consistency.</p>
Application & Finish	<p>At the time of application, surfaces should be saturated surface dry (SSD) with no standing water. Mortar must be scrubbed into the substrate, filling all pores and voids. Force material against edge of repair, working toward center. After filling repair, consolidate, then screed. Material may be applied in multiple lifts. The thickness of each lift not to be less than 1/2 inch minimum.</p> <p>Where multiple lifts are required score top surface of each lift to produce a roughened surface for next lift. Allow preceding lift to reach final set, 30 minutes minimum before applying fresh material. Saturate surface of the lift with clean water. Scrub fresh mortar into preceding lift. Allow mortar to set to desired stiffness, then finish with wood or sponge float for a smooth surface, or texture as required.</p> <p>For repairs greater than 1 inch in depth, the use of SikaRepair 222 extended with coarse aggregate, and appropriate formwork is also recommended.</p> <p>Important: Maximum bond is achieved with application of a scrub coat on properly prepared, saturated surface dry (SSD) substrate.</p>
Curing	<p>As per ACI recommendations for portland cement concrete, curing is required. Moist cure with wet burlap and polyethylene, a fine mist of water or a water based compatible curing compound. Curing compounds adversely affect the adhesion of following lifts of mortar, leveling mortar or protective coatings. Moist curing should commence immediately after finishing. Protect freshly applied mortar from direct sunlight, wind, rain and frost.</p>
Limitations	<ul style="list-style-type: none"> ■ Application thickness: (with water and diluted Latex R) Minimum 1/4 inch (6 mm). Maximum in one lift 1.5 inch (38 mm) ■ Application thickness: (with undiluted Latex R) Minimum 1/8 inch (3 mm). Maximum in one lift 1.5 inch (38 mm) ■ Minimum ambient and surface temperatures 45°F (7°C) and rising at time of application. ■ Use only potable water. ■ Do not use solvent-based curing compound. ■ As with all cement based materials, avoid contact with aluminum to prevent adverse chemical reaction and possible product failure. Insulate potential areas of contact by coating aluminum bars, rails, posts etc. with an appropriate epoxy such as Sikadur Hi-Mod 32.
Caution Irritant	<p>Suspect carcinogen - Contains portland cement and sand (crystalline silica). Skin and eye irritant. Avoid contact. Dust may cause respiratory tract irritation. Avoid breathing dust. Use only with adequate ventilation. May cause delayed lung injury (silicosis). IARC lists crystalline silica as having sufficient evidence of carcinogenicity in laboratory animals and limited evidence of carcinogenicity in humans. NTP also lists crystalline silica as a suspect carcinogen. Use of safety goggles and chemical resistant gloves is recommended. If PELs are exceeded, an appropriate, NIOSH approved respirator is required. Remove contaminated clothing.</p>
First Aid	<p>In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately with plenty of water for at least 15 minutes, and contact a physician. For respiratory problems, remove person to fresh air.</p>
Clean Up	<p>In case of spillage, scoop or vacuum into appropriate container, and dispose of in accordance with current, applicable local, state and federal regulations. Keep container tightly closed and in an upright position to prevent spillage and leakage. Mixed components: Uncured material can be removed with water. Cured material can only be removed mechanically.</p>

KEEP CONTAINER TIGHTLY CLOSED
NOT FOR INTERNAL CONSUMPTION
CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

KEEP OUT OF REACH OF CHILDREN
FOR INDUSTRIAL USE ONLY

Sika warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current technical data sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor.

NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES.

Visit our website at www.sikausa.com

1-800-933-SIKA NATIONWIDE

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Phone: 800-933-7452
Fax: 201-933-6225

Sika Canada Inc.
601 Delmar Avenue
Pointe Claire
Quebec H9R 4A9
Phone: 514-697-2610
Fax: 514-694-2792

Sika Mexicana S.A. de C.V.
Carretera Libre Celaya Km. 8.5
Corregidora, Queretaro
C.P. 76920 A.P. 136
Phone: 52 42 25 0122
Fax: 52 42 25 0537



Vector™

Ebonex®

Discrete anodes for impressed current cathodic protection

Description

Ebonex is a discrete impressed current cathodic protection (ICCP) anode that utilizes an innovative ceramic/titanium composite with an integral gas venting system. The anode system includes Ebofix grout, a high density, acid absorbent grout for long term stability.

Ebonex discrete anodes are available in a range of sizes and diameters to provide excellent design flexibility. Ebonex discrete anodes satisfy the 100mV potential shift requirement for effective cathodic protection as specified under National Association of Corrosion Engineers Standard RP 0290.

Applications

- Bridges
- Parking garages
- Marine structures
- Steel framed buildings

Features and Benefits

- **Gas venting** - no buildup of anodic gases. Can be installed under fiber-reinforced polymer (FRP) strengthening systems, membranes, and coatings.
- **Embedded installation** - no added dead weight or increase to physical dimensions of structure from thick overlays.
- **Long lasting** - 25+ year service life, the longest of any discrete CP anode system.
- **Highest level of protection** - satisfies the 100mV depolarization criteria for effective cathodic protection.
- **Proven technology** - field verified performance.
- **Cost competitive** - compared to other types of ICCP anodes.
- **Deep installation** - addresses multi-levels of steel and difficult access.
- **High operating current** - suitable for use in areas of high steel density.
- **Versatile** - can be used in new construction as a preventative measure.

Specification

Where indicated, cathodic protection to reinforced concrete elements shall be provided by Ebonex discrete composite anodes as supplied by Vector Corrosion Technologies. Ebonex anodes shall be capable of maintaining long term stability at current densities of up to 900mA/m² (of anode surface). The Ebonex discrete anodes shall be gas vented and shall be grouted in place using Ebofix grout, a thixotropic high density, electrochemically compatible grout.

How It Works

ICCP mitigates corrosion activity by supplying sufficient electrical current from an external source to overcome the on-going corrosion current in the structure. Ebonex anodes are permanently installed into the structure. An external DC power source provides the source of electrical current that overpowers corrosion activity. The anodes are connected to the positive (+) terminal. According to industry standards, an ICCP system is considered to be effective when the system polarizes the reinforcing steel sufficiently to result in a 100mV depolarization after the system is turned off.



Ebonex anodes are available in a range of sizes to suit project requirements

Level of Protection	Description	Ebonex
Corrosion Prevention	Preventing new corrosion activity from initiating	
Corrosion Control	Significantly reducing on-going corrosion activity	
Cathodic Protection	Highest level of protection intended to stop on-going corrosion activity	•

Design Criteria

Ebonex is a discrete cathodic protection system providing long term durability to both new and existing structures under highly aggressive conditions. In line with other cathodic protection systems, Ebonex discrete anode systems should be designed by corrosion specialists and installed by knowledgeable and experienced contractors.

Ebonex Type	Diameter x length (mm)	Current rating (mA)
CP07/100	7 x 100	2.0
CP10/100	10 x 100	2.8
CP10/150	10 x 150	4.2
CP18/100	18 x 100	5.1
CP18/200	18 x 200	10.2
CP18/300	18 x 300	15.2
CP28/100	28 x 100	7.9
CP28/300	28 x 300	23.7
CP28/600	28 x 600	47.5

Installation Instructions

Preparation

Ebonex discrete anodes are installed in pre-drilled holes 4 to 8 mm larger than the nominal anode diameter and typically no further than 600 mm apart. The holes and Ebonex discrete anodes should be located to minimize their proximity to the steel



Vector™ Ebonex®

reinforcement in order to provide an even current distribution to the steel within the local vicinity.

Cut a saw cut of minimum 10 mm depth and 8 mm width into the concrete or mortar joint between the holes. This saw cut will accommodate the titanium feeder wire interconnecting the Ebonex anodes, and the gas-ventilation tubing. A 3 mm saw cut can be used if the venting pipes are not interconnected. Prior to application the holes and saw cuts should be blown or vacuum cleaned of all debris and pre-soaked with water.

Mixing

Ebofix grout should be mixed with a slow speed drill (400-500 rpm) and paddle mixer. Place 3.0 litres of potable water into a suitable mixing container, add one full 10 kg bag of Ebofix grout and mix for three minutes until fully homogeneous.

Installation

Standing water should be removed from the drilled anode hole and the Ebofix grout placed to the rear of the hole to avoid air entrapment, ensuring sufficient grout is placed to cover the entire length of the active Ebonex discrete anode once installed. The thixotropic nature of Ebofix grout will prevent significant flow from vertical and overhead holes. Wet each Ebonex anode with clean water, but do not immerse for more than 10 seconds, before gently inserting into the hole. Ensure the vent pipe is unobstructed and that sufficient tail wire remains exposed to enable connection with the feeder wire.

Place the Ebofix grout within 30 minutes of mixing to gain benefit of the expansion system and allow to cure for a minimum of 24 hours, without physical disturbance. When cured, the open end of the gas vent network can be directed to a well-ventilated location.

Connect strings of Ebonex discrete anodes together as recommended by the CP design engineer using non-coated titanium feeder wire. All wire jointing requires the use of titanium metal crimps, secured using an appropriate crimping tool.

After connections have been made continuity should be tested with a resistance meter. Any reading found to have a resistance greater than 1 ohm require recrimping the connection. When the integrity of the connection is established the tail of each Ebonex discrete anode can be gently bent, thus settling the wire into the saw cut groove.

The saw cut is filled with Ebofix grout or a cementitious mortar, and left undisturbed for a minimum of 4 days before connecting to the power system.

Precautions

In chloride contaminated structures, particular attention should

be paid to the control of applied voltage. Potentials greater than 7 volts should not be applied to the titanium connecting wires. Performance of the Ebonex discrete anode is dependent upon the correct design, installation and maintenance of the cathodic protection system. For further information consult the local Vector office.

Packaging

Ebonex discrete anode	Anode with 500 mm tail wire (packaging varies depending upon the anode dimensions)
Ebofix grout	10 kg bags
Wire pack	Titanium feeder wire 40 m x 1.5 mm diameter
Crimping pack	80 titanium crimps
Venting pack	20 m PVC tube plus 40 connecting T-pieces
Crimping tool	Crimping tool plus plattens

Storage

Store both the Ebonex discrete anodes and Ebofix grout in dry conditions in their original unopened packaging. Ebofix grout has a shelf life of 12 months.

Health and Safety

There are no known health hazards associated with Ebonex discrete anodes.

Ebofix grout is alkaline and should not come into contact with the skin and eyes. Avoid inhalation of dust during mixing. Gloves, goggles and dust mask should be worn. If contact with skin occurs, wash with water. Splashes to eyes should be washed immediately with plenty of clean water and medical advice sought.

Ebonex discrete anodes and Ebofix grout are non-flammable.

Related Documents

A range of related Ebonex documents are available. For more information, contact Vector Corrosion Technologies.

About Vector

Vector Corrosion Technologies is a member of the Vector Construction Group, a privately owned corporation with 11 offices throughout Canada and the United States. Vector takes pride in offering technically advanced yet cost effective solutions for concrete structures subject to corrosion damage and has earned numerous awards and patents for product innovation. As evidenced by the Corporate Safety and Environmental Policies, Vector is committed to a safe, healthy and sustainable environment.

Vector™

Galvashield® CC

Embedded Galvanic Anode Units for Corrosion Control

Description

Galvashield CC embedded galvanic anode units are used to control on-going corrosion and to prevent the initiation of new corrosion activity in concrete structures. Galvashield CC consists of a sacrificial zinc anode core that is activated by the surrounding specially formulated precast cementitious mortar. The cylindrical unit, available in a variety of standard sizes, is quickly and easily installed into concrete that is mechanically sound but has on-going corrosion activity. Once installed, the zinc anode corrodes preferentially to the surrounding rebar, thereby providing galvanic corrosion control to the adjacent reinforcing steel. Custom size units are available for specific project needs.

Applications

- Balconies
- Columns and beams
- Bridge decks
- Parking garages
- Piers and wharfs
- Prestressed concrete
- Post-tensioning anchors

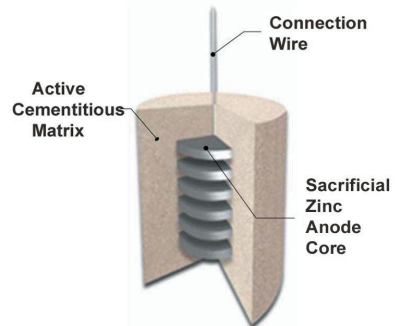
Features and Benefits

- **Proven technology** - supported by independent test program.
- **Focused protection** - discrete anodes can be installed to provide corrosion protection in areas with high corrosion potentials or active corrosion.
- **Economical** - save money by only protecting the remaining chloride-contaminated (unrepaired) areas.
- **Versatile** - effective in chloride-contaminated and carbonated concrete. Can be used for both conventionally reinforced and prestressed or post-tensioned concrete.
- **User friendly** - installation is quick and easy.
- **Low maintenance** - requires no external power source or system monitoring.
- **Measurable** - anode performance can be easily monitored if required.
- **Long lasting** - 10 to 20 year service life* reduces the need for future repairs.

*As with all galvanic protection systems, service life is dependent upon a number of factors including reinforcing steel density, concrete conductivity, chloride concentration, humidity and anode spacing.

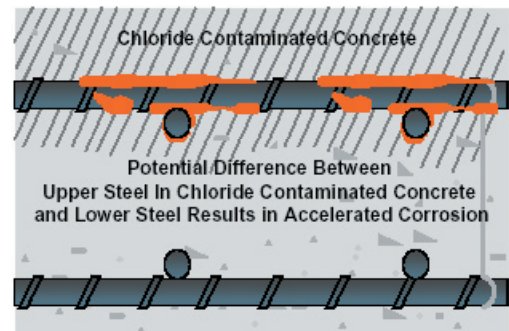
Specification

Embedded galvanic anodes shall be Galvashield CC (specify product number, ie. CC65), as supplied by Vector Corrosion Technologies. Galvashield CC is a pre-manufactured unit consisting of zinc in compliance with ASTM B418-95a Type I cast around an integral bright steel tie wire for making connection to the reinforcing steel and encased in an activated cementitious mortar with pH of 14 or greater. The cementitious mortar around the zinc anode shall contain no chlorides or other corrosive constituents detrimental to the reinforcing steel as per ACI 222R.

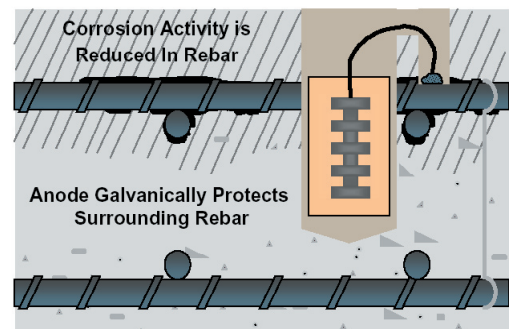


Cut-away of Galvashield CC

Level of Protection	Description	Galvashield CC
Corrosion Prevention	Preventing new corrosion activity from initiating	•
Corrosion Control	Significantly reducing on-going corrosion activity	•
Cathodic Protection	Highest level of protection intended to stop on-going corrosion activity	



Chloride contamination causes corrosion in reinforced concrete



Galvashield CC mitigates active corrosion

Vector™ Galvashield® CC

How It Works

When two dissimilar metals are coupled together in an electrolyte, the metal with the higher potential for corrosion (more electronegative) will corrode in preference to the more noble metal. In concrete repair applications, the zinc core of the Galvashield CC unit will corrode in favor of the reinforcing steel, thus providing corrosion control to the adjacent reinforcing steel.

Design Criteria

Standard Units

Unit Type	Description	Unit Size diameter x length	Minimum Hole Size diameter x depth
Galvashield CC65	Standard unit for moderate steel density	1 ¾ x 2 ½ in. (46 x 62 mm)	2 x 3 ¾ in. (50 x 95 mm)
Galvashield CC100	Larger unit for higher steel density	1 ¾ x 4 in. (46 x 100 mm)	2 x 5 ⅞ in. (50 x 130 mm)
Galvashield CC135	Slim-fit for congested reinforcement	1 ⅞ x 5 ⅞ in. (29 x 135 mm)	1 ¼ x 6 ½ in. (32 x 165 mm)

Galvashield CC65 and CC135

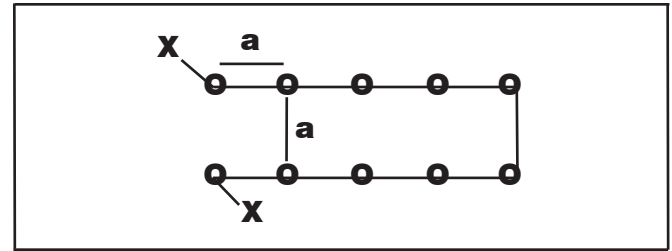
Steel density ratio (steel surface area/concrete surface area)	Maximum grid dimensions* in. (mm)
< 0.2	28 in. (700 mm)
0.21 - 0.4	24 in. (600 mm)
0.41 - 0.54	20 in. (500 mm)
0.55 - 0.67	18 in. (450 mm)
0.68 - 0.80	16 in. (400 mm)
0.81 - 0.94	15 in. (380 mm)
0.95 - 1.07	14 in. (355 mm)
1.08 - 1.2	13 in. (335 mm)

Galvashield CC100

Steel density ratio (steel surface area/concrete surface area)	Maximum grid dimensions* in. (mm)
0.55 - 0.94	20 in. (500 mm)
0.95 - 1.17	18 in. (450 mm)
1.18 - 1.41	16 in. (400 mm)
1.42 - 1.64	15 in. (380 mm)
1.65 - 1.88	14 in. (355 mm)
1.89 - 2.11	13 in. (335 mm)

*Maximum grid dimensions are based on typical conditions. Spacing should be reduced as appropriate for severe environments or to extend the expected service life of the anode.

Typical layout for series connection



- Galvashield CC units
- ✕ Minimum number of rebar connections
Interconnecting cable
- a Maximum spacing

Installation Instructions

The location and spacing of the Galvashield CC units shall be on a grid pattern as specified by the engineer. Using a rebar locator, locate all existing steel within the area designated for protection and mark areas to drill unit installation holes. When possible, units should be installed a minimum of 4 in. (100 mm) from reinforcing grid.

Series Connection - a single circuit shall contain no more than 10 Galvashield CC units. Drill a minimum of two ½ in. (12 mm) rebar connection holes per string of anodes. Saw cut a single continuous groove approximately ¼ in. (6 mm) wide by ½ in. (12 mm) deep into the concrete to interconnect rebar connection holes and anode connection holes.

Individual Connection - drill one rebar connection hole per unit location. Saw cut a groove approximately ¼ in. (6 mm) wide by ½ in. (12 mm) deep into the concrete to interconnect the rebar connection hole and anode connection hole.

Reinforcing steel connections should be made using the Vector Rebar Connection Kit. Place the weighted end of the connector into the drilled hole until the steel coil contacts the reinforcing steel. Feed the steel connector wire through the Vector Setting Tool and set into place by striking with a hammer.

Connect the units directly to the rebar connection wire using the supplied wire connector. If installing in series, connect the units to the interconnecting cable with a wire connector (cable and wire connectors are available as the Vector Anode Connection Kit). Verify continuity between unit locations and rebar connections with a multi-meter. A resistance of 1 ohm or less is acceptable.

Drill holes as per the dimensions listed above to accommodate the anodes. Presoak the units for a minimum of 10 to a maximum of 30 minutes in a shallow water bath. Galvashield Embedding Mortar should be used to install the still wet units into presoaked (saturated-surface dry) holes. Place the mixed embedding mortar into the bottom ⅔ of each hole and slowly press in the unit allowing the mortar to fill the annular space ensuring there are no air voids between the unit and the parent concrete. The minimum unit cover depth shall be ¾ in. (20 mm).



Vector™

Galvashield® CC

Place wires into grooves and top off unit holes and saw cuts flush to the concrete surface with embedding mortar. Embedding mortar should be wet cured or cured with a curing compound and protected from traffic for 24 hours.

Precautions

Galvashield CC units are not intended to address or repair structural damage. Where structural damage exists, consult a structural engineer.

Galvashield CC anodes are designed to provide galvanic corrosion control. Corrosion control products significantly reduce or stop on-going corrosion. Concrete repairs should be completed using Galvashield XP units around the boundary of the patch prior to installing Galvashield CC units in the remaining unrepaired areas. For more information on corrosion mitigation strategies, contact Vector Corrosion Technologies.

Packaging

Galvashield CC units	20 units per box
Galvashield Embedding Mortar	11 lb. (5 kg) bags one bag per 10-20 units
Vector Rebar Connection Kit	20 rebar connectors per box
Vector Anode Connection Kit	50 ft. (15.2 m) insulated cable 25 wire connectors
Vector Setting Tool	1 unit per box

Storage

Store in dry conditions in the original unopened boxes. Avoid extremes of temperature and humidity. Units should be installed within one year.

Health and Safety

As with all cement-based materials, contact with moisture can release alkalis which may be harmful to exposed skin. Galvashield CC and Galvashield Embedding Mortar should be handled with suitable gloves and other personal protective equipment in accordance with standard procedures for handling cementitious materials. Mix left over water from the unit bath with cementitious material and dispose by normal means after hardening. Additional safety information is included in the Material Safety Data Sheet.

Related Documents

A range of related Galvashield CC documents are available including independent product evaluations, installation instructions, specifications, project histories, applications, price list, MSDS etc. For more information, contact Vector Corrosion Technologies.

About Vector

Vector Corrosion Technologies is a member of the Vector Construction Group, a privately owned corporation with 11 offices throughout Canada and the United States. Vector takes pride in offering technically advanced cost effective solutions for concrete structures subject to corrosion damage and has earned numerous awards and patents for product innovation. As evidenced by the Corporate Safety and Environmental Policies, Vector is committed to a safe, healthy and sustainable environment.

Vector™

Norcure® Chloride Extraction

Electrochemical chloride extraction process for chloride-contaminated structures

Description

Norcure electrochemical chloride extraction (ECE) is a treatment which a) extracts chloride ions from contaminated concrete and b) reinstates the passivity of steel reinforcement. Chloride extraction is carried out by temporarily applying an electric field between the reinforcement in the concrete and an externally mounted anode mesh. During the process chloride ions are transported out of the concrete. At the same time, electrolysis at the reinforcement surface produces a high pH environment. This process returns the steel reinforcement to a passive condition.

Advantages

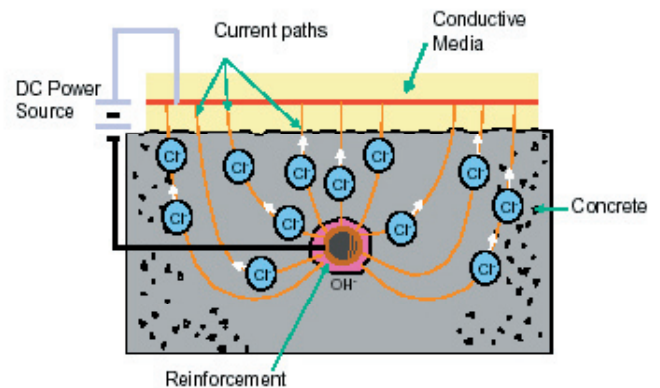
Norcure chloride extraction offers major advantages over other methods of concrete repair.

- The cause of corrosion is addressed and removed.
- The success of the treatment is documented on-site.
- The rebars are passivated throughout the treated area not just in isolated areas.
- The non-destructive nature of the treatment results in vastly reduced concrete break-out, which means:
 - Major time-savings
 - Less noise, dust and environmental pollution
 - No need for expensive structural support
 - Reduced risk of inducing micro-cracks
- The Norcure Chloride Extraction process is silent.
- The need for permanent electronic monitoring is eliminated.
- Architectural and exposed aggregate finishes can be maintained.
- Fixed prices can frequently be offered.

General Technical Specification

The Norcure Chloride Extraction treatment is carried out in full accordance with the Operators' Manual. To obtain a comprehensive guideline specification for the Norcure Chloride Extraction process, contact Vector Corrosion Technologies.

Anode	Metallic mesh temporarily mounted on concrete surface
Cathode	Existing steel reinforcement
Electrolyte	Fresh water (calcium hydroxide may be added)
Current density	1 A/m ² of concrete surface
Treatment time	Four to eight weeks
Applied voltage	Between 10 to 40 V DC



Norcure Chloride Extraction process mitigates corrosion in chloride contaminated structures

Preparation Prior to Treatment

- Any existing surface finishes shall be removed.
- Any cracks, spalls and delaminations shall be located and repaired using an approved cementitious mortar.
- All metallic features on the concrete surface shall be located and insulated, or removed.
- The thickness of the concrete cover shall be determined and built up to a minimum of 10 mm if necessary.
- Reinforcement continuity shall be examined and, if necessary, improved to give full continuity.

Treatment

- Treatment sections shall be identified to ensure even current distribution within each section.
- Electrical connections to the reinforcement shall be established.
- Test locations for concrete sampling shall be determined and marked.
- The chosen anode system, consisting of an anode mesh and an electrolyte reservoir, shall be installed.
- Electrical connections to the anode mesh shall be established.
- The leads from the reinforcement shall be connected to the negative pole of the rectifier unit(s).
- The leads from the anode mesh shall be connected to the positive pole of the rectifier unit(s).
- A voltage shall be adjusted to give approximately 1 A/m² of concrete surface.
- Current, voltage and efficiency of the anode system shall be controlled and, if necessary, adjusted throughout the treatment.

Post-treatment

- When the process is complete, the anode system shall be removed and the concrete surface cleaned and allowed to dry.
- If required, the concrete surface shall be treated with an approved protective/decorative coating system.

4001 - 2007Apr01

Vector Corrosion Technologies Ltd. 474 Dovercourt Drive Winnipeg, MB R3Y 1G4
 Vector Corrosion Technologies, Inc. 2237 Twelve Oaks Way, #103 Wesley Chapel, FL 33543
 Vector products are guaranteed against defects in materials and workmanship, and are sold subject to standard terms and conditions of sale, copies of which may be obtained upon request. While Vector Corrosion Technologies endeavors to ensure the information and recommendations it supplies are accurate, it cannot accept any liability arising from use of its products because it has no control over where and how its products are applied. User shall determine the suitability of the products for the intended use and assume all risks and liability in connection therewith. For professional use only; not for sale to or use by the general public.

Vector is a trademark. The Vector logo is a registered trademark. Norcure is a registered trademark of Fosroc International Ltd.
 Patents: US 4832803, 5198082, 5228959, 5320722, 5407543, 5538619, 6027633, 6183624
 Printed in Canada



www.vector-corrosion.com

CAN: Phone: (204) 489-6300 Fax: (204) 489-6033
 USA: Phone: (813) 830-7566 Fax: (813) 830-7565

Email: info@vector-corrosion.com

Sika FerroGard® 903

Penetrating, corrosion inhibiting, impregnation coating for hardened concrete

Description	Sika FerroGard 903 is a corrosion inhibiting impregnation coating for hardened concrete surfaces. It is designed to penetrate the surface and then to diffuse in vapor or liquid form to the steel reinforcing bars embedded in the concrete. Sika FerroGard 903 forms a protective layer on the steel surface which inhibits corrosion caused by the presence of chlorides as well as by carbonation of concrete.
How it Works	<p>Sika FerroGard 903 is a combination of amino alcohols, and organic and inorganic inhibitors that protects both the anodic and cathodic parts of the corrosion cell. This dual action effect dramatically delays the initiation of corrosion and greatly reduces the overall corrosion activity.</p> <p>Sika FerroGard 903 protects the embedded steel by depositing a physical barrier in the form of a protective layer on the surface of the steel reinforcement. This barrier inhibits corrosion of the steel.</p>
Where to use	<p>Sika FerroGard 903 is recommended for all steel-reinforced, prestressed, precast, post tensioned or marine concrete. Use of Sika FerroGard 903:</p> <ul style="list-style-type: none">■ Steel-reinforced concrete, bridges and highways exposed to corrosive environments (deicing salts, weathering)■ Building facades and balconies■ Steel-reinforced concrete in or near a marine environment■ Parking garages■ Piers, piles, and concrete dock structures■ As part of Sika's system approach for buildings and civil engineering structures
Advantages	<p>Sika FerroGard 903 offers owners, specifiers, port authorities, DOTs, and engineers, a new technology in corrosion inhibition that can easily be applied to the surface of existing concrete to extend the service life of any reinforced concrete structure.</p> <ul style="list-style-type: none">■ Protects against the harmful effects of corrosion by penetrating the surface of even the most dense concrete and diffusing to the steel to inhibit corrosion.■ Enhances the durability of reinforced concrete.■ Does not require concrete removal.■ Environmentally sound.■ Does not contain calcium nitrite.■ Easily applied by either spray or roller to all existing reinforced concrete.■ Can be applied to reinforced concrete that already exhibits corrosion.■ Adds additional benefits when used prior to protective coatings in concrete restoration systems.■ Water based for easy handling and application.■ Not a vapor barrier; allows vapor diffusion.■ FerroGard has been proven effective in both laboratory (ASTM G109/Cracked Beams) and field analysis.
Coverage	For normal concrete, application is 200 ft. ² /gal. each coat. A minimum of two coats is always required. For dense concrete, application may exceed 300 ft. ² /gal. Therefore, more than two coats may be required to achieve the total application rate: 100 ft.²/gal.
Packaging	5 gallon pails with spout, 55 gallon drums.

Typical Data [at 73°F(23°C)]

Shelf life	18 month minimum in original, unopened container
Storage Conditions	Store at 40°-95°F (4°-35°C). Protect from freezing. If frozen, discard.
Color	Pale Yellow
Viscosity	15 cps
Flash Point	None (water based)
Density	1.13 (9.4 lbs./gal.)
pH	11 (±1)
Application Rate	100 ft. ² /gal. total application rate

How to Use

Surface preparation Before applying Sika FerroGard 903 be sure the surface is clean and sound. Remove all dirt, dust, oil, grease, efflorescence or existing coatings from concrete surface by steam cleaning, waterblasting or slightly sandblasting. Allow concrete surface to dry prior to application of Sika FerroGard 903. The dryer the surface the better the penetration and effectiveness.

Key Criteria	Performance Level	Test Method/Institute
Corrosion inhibition	FerroGard corrosion inhibitors delay the onset of corrosion and reduce the rate of corrosion by 65% versus control specimen after 1 year.	1
Penetration Rate in hardened concrete	FerroGard 903 penetrates independently of orientation (horizontal, vertical, overhead) at a rate of 1/10 to 4/5 inches (2.5 to 20 mm) per day, depending on the density of the concrete.	2
Depth of Penetration	FerroGard 903 penetrates up to 3 inches (76 mm) in 28 days.	2
Protective layer on steel	FerroGard 903 forms a protective layer on the reinforcing steel of high integrity measured at as much as 100 Å in thickness.	3
Displacement of chlorides from steel surface	FerroGard 903 forms a continuous film on the reinforcing steel and displaces chloride ions from the steel surface.	3
Corrosion Rate Field Monitoring	Reduction of corrosion rates in excess of 65%.	4

Test Method/Institute:

1. Cracked Concrete Beam Test (adapted from ASTM G109).
2. Secondary Neutron Mass Spectroscopy (SNMS) / Institute for Radiochemistry, Karlsruhe (Germany), Prof. Dr. J. Goschnick.
3. X-ray Photon Spectroscopy (XPS) and Secondary Ion Mass Spectroscopy (SIMS) / Brundle and Associates, San Jose, CA and University Heidelberg (Germany), Prof. M. Grunze.
4. Performance of Corrosion Inhibitors in Practice, Graeme Jones, C-Probe Technologies Ltd., 2000.

Application

Sika FerroGard 903 is applied by roller, brush or spray on concrete surfaces. When spraying, use a conventional airless spray system or hand-pressure equipment. **A minimum of two coats is always recommended.** Dense substrates may require more coats. Waiting time between coats of Sika FerroGard 903 is at least 1 hour. Allow a minimum of one day to allow Sika FerroGard 903 to dry and penetrate.

When Sika FerroGard 903 is used prior to the application of a repair mortar, concrete overlay, protective coating, Sikafloor system or any other application, care must be taken to remove any residue remaining on the surface from the application of Sika FerroGard 903. Clean the substrate in such a manner (i.e. push the water in one direction away and off from the surface to be treated) to completely remove any residue. Horizontal surfaces require pressure washing (2,000 psi minimum) or grit blasting to remove the residue. Vertical surfaces may be rinsed with water, pressure washed or grit blasted. The use of Sika Armatex 110 EpoCem as a bonding agent prior to the application of repair mortars or concrete overlays is suggested. Drying times depend on environmental conditions, absorbency of the substrate and maximum recommended moisture content for the subsequently applied system.

Limitations

- Minimum ambient and substrate temperatures 35°F.
- Do not apply when temperature is expected to fall below 35°F within 12 hours.
- If the applied surfaces will be submerged after the application of Sika FerroGard 903, a waterproofing coating must be applied prior to submersion.
- Substrate should be as dry as possible prior to the application.
- Protect glass, wood, brick, galvanized steel, copper and exposed aluminum during the application.
- Maximum chloride content of concrete structures intended to be treated with Sika FerroGard 903 is 6 lbs./y³ (measured at the level of the reinforcing steel). For levels up to 10 lbs./y³, consult technical service.

Caution

Irritant - Skin and eye irritant. Vapors may cause respiratory tract irritation. Use only with adequate ventilation. Use of safety goggles and chemical resistant gloves is recommended. Remove contaminated clothing.

First Aid

In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately with plenty of water for at least 15 minutes; contact physician immediately. For respiratory problems, remove person to fresh air. Wash clothing before re-use.

Clean Up

In case of spills or leaks, wear suitable protective equipment, contain spill, collect with absorbent material, and transfer to a suitable container. Ventilate area. Avoid contact. Dispose of in accordance with current, applicable local, state, and federal regulations.

KEEP CONTAINER TIGHTLY CLOSED
NOT FOR INTERNAL CONSUMPTION

KEEP OUT OF REACH OF CHILDREN
FOR INDUSTRIAL USE ONLY

CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

Sika warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current technical data sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor.

NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES.

Visit our website at www.sikausa.com

1-800-933-SIKA NATIONWIDE

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Phone: 800-933-7452
Fax: 201-933-6225

Sika Canada Inc.
601 Delmar Avenue
Pointe Claire
Quebec H9R 4A9
Phone: 514-697-2610
Fax: 514-694-2792

Sika Mexicana S.A. de C.V.
Carretera Libre Celaya Km. 8.5
Corregidora, Queretaro
C.P. 76920 A.P. 136
Phone: 52 42 25 0122
Fax: 52 42 25 0537



Quality Certification Numbers: Lyndhurst: FM 69711 (ISO 9000), FM 70421 (QS 9000), Marion: FM 69715, Kansas City: FM 69107, Santa Fe Springs: FM 69408

Sika and FerroGard are registered trademarks. Made in USA. Printed in USA.

