



Archipelagos Not Islands: Linking Resilience of Buildings with Infrastructure Lifelines

Municipal Perspective & Post Earthquake Evaluation Tools

Dane Doleman, P.Eng. ENV SP
Structures Engineer
Understanding Risk BC
April 17th, 2018

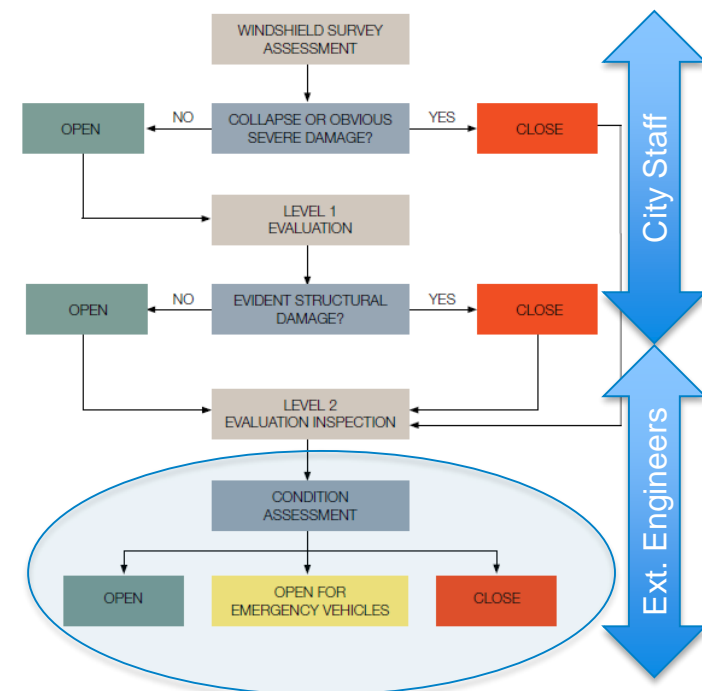
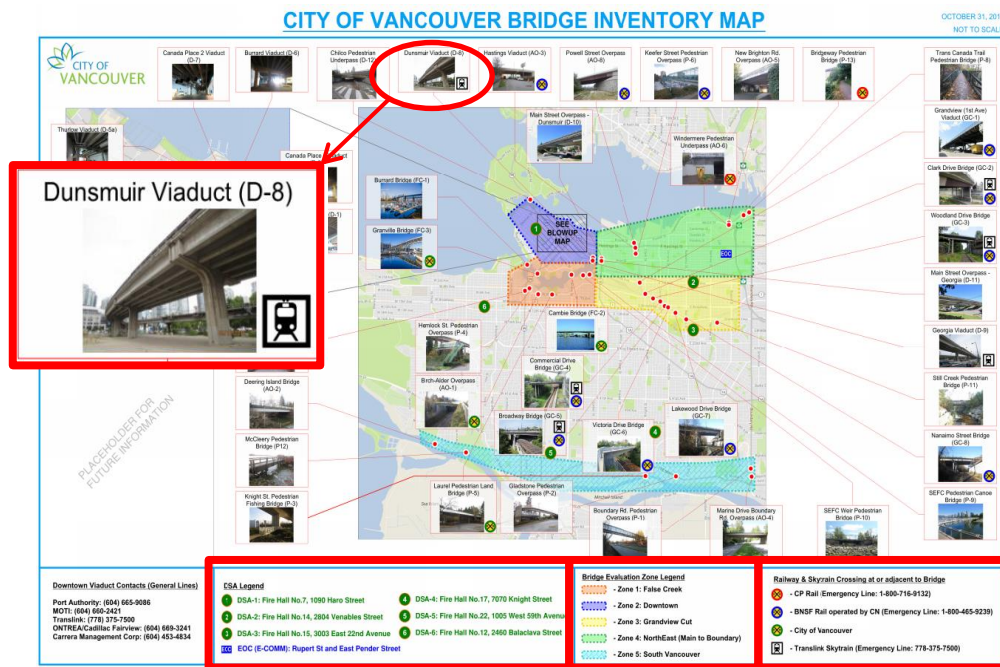
- Changing expectations
- Re-assessing network (bridges) vulnerability
- Post earthquake evaluation tools
 - Level 1 Inspection Guide
 - Seismic Performance Drawing
(we get to test in May 2019)



- Performance based design – making us ask questions
- Moving beyond life safety → service disruption → return to service
- Becoming embedded in planning & design projects

Re-assessing Network Vulnerabilities

- Inventory (44 bridges) of varying types and age
- Seismic screening level assessments - complete
- Detailed assessments proceeding (risk, vulnerability, impacts*), upgrades to follow.
- Recent focus on post earthquake response.



Post Earthquake Inspection Guide

- Supports rapid damage assessment
- Tailored to suit City personnel
- Orientation, guided process
- Standardized forms and procedures

STRUCTURE ID: GC-3 STRUCTURE NAME: WOODLAND DRIVE BRIDGE



BRIDGE SPECIFIC REFERENCE INFORMATION FOR POST-EARTHQUAKE LEVEL 1 INSPECTION



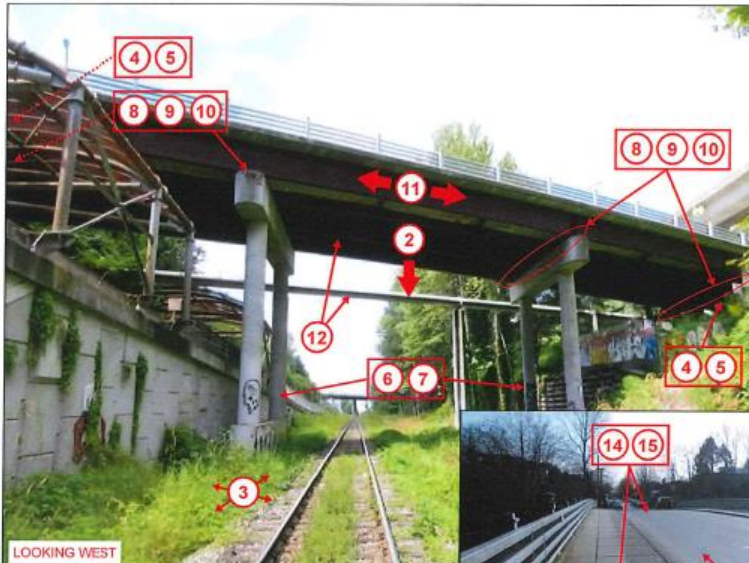
LOCATION OF STRUCTURE WITHIN CITY LIMITS



LOCATION OF STRUCTURE ON STREET MAP



BEST VIEWPOINT & ACCESS LOCATIONS



LOOKING WEST

• If possible, the **best** **vertical** approach to the bridge is from the north end. This will provide optimal access to perform an assessment of the Skytrain flyover (see next bullet) and is the side with the only means of access down to the central piers.
 • There is a **Skytrain (Expo Line) Flyover** crossing directly above the north end of the bridge. While not within the City's inventory its condition may necessitate the closure of the Woodland Drive Bridge.
 • There is a **Water Main** pipe structure just west of the bridge. Appropriate caution should be exercised as the pipe may have ruptured during the EQ.
 • Access to the **Abutments** is best achieved at the west side of the north abutment, and the east side of the south abutment (a type 12 key is required). Access to the bases of the piers is only possible from the north end of the bridge as the Millennium Skytrain cuts off access from the south.
 • Misalignment in the **Train Tracks** below the structure is a strong indicator that soil displacement has occurred which can affect the stability of the abutments.
 • **Access Key Required:** A #12 padlock key is required to access gates as shown.

STRUCTURE SPECIFIC NOTES



NORTH ABUTMENT

INSPECTION CHECKLIST

1. Is bridge open to traffic?
2. Has the bridge collapsed (partially or totally)?
3. Is there any obvious soil cracking/damage nearby?
4. Have the abutments tilted or experienced loss of soil?
5. Is there any cracking in the abutment walls?
6. Have the piers tilted?
7. Is there any cracking of the piers (columns, crossbeams, bracing)?
8. Do the bearings appear shifted?
9. Do the bearings show any damage?
10. Do the steel girders appear shifted?
11. Is there any cracking or warping of the steel girders?
12. Are there any utilities damaged?
13. Is there any vertical or horizontal misalignment of the roadway/riding profile?
14. Do the deck joint openings appear excessive?
15. Is there a vertical or horizontal displacement of joints?

CITY OF VANCOUVER POST EARTHQUAKE INSPECTION GUIDE

BRIDGE ENGINEERING SERVICES – TASK WA1
 OUR REF: 2008-016-PP1001-0
 2017 SEPTEMBER

PREPARED BY:
 Todd McIlmorn, P.Eng.
 Claudio Oates, P.E., SE

REVIEWED BY:
 Daniel Gagnon, P.Eng.

COWI NORTH AMERICA LTD.
 101-788 Harbourside Drive
 North Vancouver, BC, Canada V7P 3R7
 Tel: 804-986-1221 Fax: 804-986-1302
 E-mail: cowi@northamericacow.com
 Website: www.cowi.com

COWI

CITY OF VANCOUVER

POST-DISASTER INSPECTION MANUAL
 for the
 CAMBIE STREET BRIDGE

Revision No: D
 September 2017

May 2014 Original Manual by Reconnaitre Engineering
 September 2017 Minor Edits by City of Vancouver

Post Earthquake Inspection Guide

- Level 1 Evaluation Work Flow for Viaduct A:

City of Vancouver - Post Earthquake Inspection Guide

LEVEL 1 EVALUATION FORM

1. Bridge and Evaluator Information



Bridge ID #: _____ Evaluators: _____
 Bridge Name: _____
 Date (YYYY-MM-DD): _____ BET Team: _____
 Arrival Time: _____ AM / PM / 24HR
 BET - Level 1 - [Zone Name] - Team [#]

SAFETY NOTE, DO NOT RISK YOUR LIFE. PERSONAL SAFETY SHOULD ALWAYS BE THE TOP PRIORITY.

2. Evaluation Checklist

QUESTIONS	YES				NO				NOT APPLICABLE				COMMENTS
	Y	N	NA	X	Y	N	NA	X	Y	N	NA	X	
GENERAL OBSERVATIONS													
1. Is bridge open to traffic?	Y	N	NA	X									
2. Has the bridge collapsed (partially or totally)?	Y	N	NA	X									
3. Is there any obvious soil cracking/damage nearby the bridge foundations?	Y	N	NA	X									
4. Have the abutments tilted and/or experienced a significant loss of soil underneath?	Y	N	NA	X									
5. Is there any cracking in the abutments?	Y	N	NA	X									
6. Have the piers tilted?	Y	N	NA	X									
OBSERVATIONS FROM GROUND													
7. Is there any cracking or buckling of the piers (columns, crossbeams, bracing)?	Y	N	NA	X									
8. Do the bearings appear shifted?	Y	N	NA	X									
9. Do the bearings show any damage?	Y	N	NA	X									
10. Do the girders appear shifted?	Y	N	NA	X									
11. Is there any cracking of the girders?	Y	N	NA	X									
12. Are there any utilities damaged?	Y	N	NA	X									
OBSERVATION FROM DECK													
13. Is there vertical or horizontal misalignment of the roadway profile? (check guardrail/barriers)	Y	N	NA	X									
14. Do deck joint openings appear excessive? (1000 mm or more, or overly stretched seal)	Y	N	NA	X									
15. Is there a vertical or horizontal displacement of joints?	Y	N	NA	X									

QUESTIONS	YES				NO				NOT APPLICABLE				COMMENTS
	Y	N	NA	X	Y	N	NA	X	Y	N	NA	X	
4. Have the abutments tilted and/or experienced a significant loss of soil underneath?	Y	N	NA	X									
5. Is there any cracking in the abutments?	Y	N	NA	X									
6. Have the piers tilted?	Y	N	NA	X									

Refer to Bridge-Specific Detailed Sheet

3. Additional Notes/Observations

4. Status of Bridge

CONCLUDED DISPOSITION OF BRIDGE (RECOMMENDATION)
 OPEN / CLOSED
 BRIDGE TAGGED ACCORDINGLY?
 YES / NO
 BRIDGE CLOSURE IN PLACE?
 YES / NO

- Notes**
- Take pictures of bridge to document condition observed. Where possible, use a reference object (person, measuring tape, other) to quantify damage as demonstrated in the sample pictures.
 - Bridges with evident damage shall be closed.
 - See reverse side for generalized sketches available for mark-up.



Sample pictures showing the use of reference elements to quantify extent of damage.

Paper copy or digital app

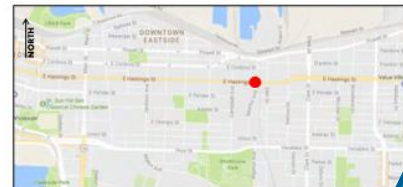
Post Earthquake Inspection Guide

Level 1 Evaluation Work Flow for Viaduct A:

STRUCTURE ID: **AO-3** STRUCTURE NAME: **HASTINGS VIADUCT**
 BRIDGE SPECIFIC REFERENCE INFORMATION FOR POST-EARTHQUAKE LEVEL 1 INSPECTION



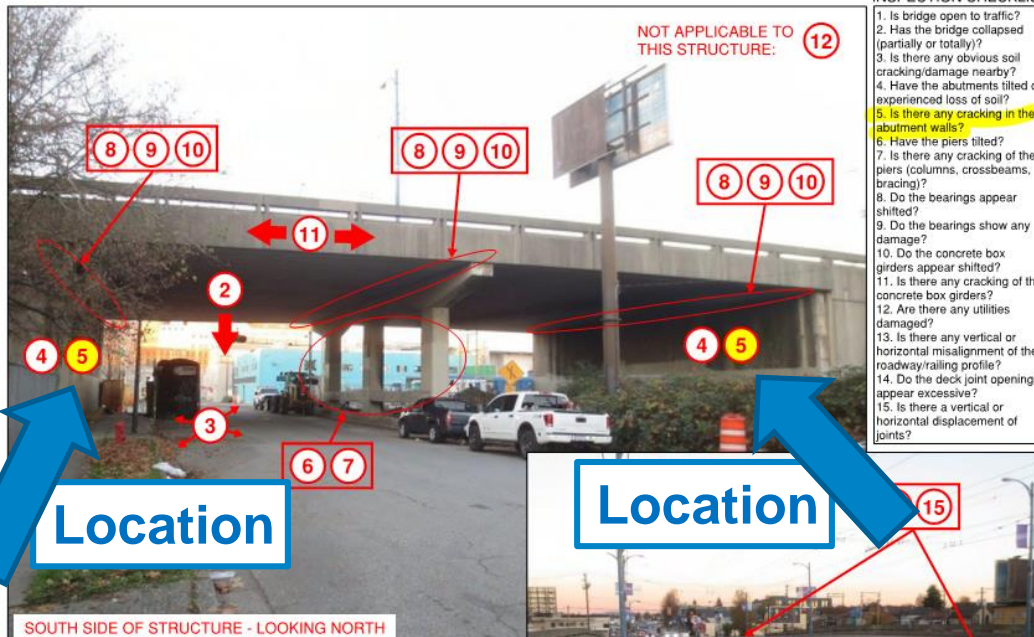
LOCATION OF STRUCTURE WITHIN CITY LIMITS



LOCATION OF STRUCTURE ON STREET MAP



BEST VIEWPOINT & ACCESS LOCATIONS



SOUTH SIDE OF STRUCTURE - LOOKING NORTH

- There is no **Ideal Arrival** approach to the bridge as access to all ends/sides is made relatively easy using local side streets.
- In general, **Access Below the Structure** is best achieved by using the streets to the north of the structure as the route to the south is more extensive (over several blocks).
- The **Bearing Shelves** at both sides of the bridge and at the central pier are not easily accessible on foot. Proper access will require equipment not anticipated to be available for the Level 1 Inspection which can make assessment of these areas difficult.
- Misalignment in the **Train Tracks** below the east span of the structure is a strong indicator that soil displacement has occurred which can affect the stability of the abutments.
- **Access Key Not Required:** There are no locked gates restricting access at structure.

STRUCTURE SPECIFIC NOTES



WEST ABUTMENT - LOOKING EAST

INSPECTION CHECKLIST

1. Is bridge open to traffic?
2. Has the bridge collapsed (partially or totally)?
3. Is there any obvious soil cracking/damage nearby?
4. Have the abutments tilted or experienced loss of soil?
5. Is there any cracking in the abutment walls?
6. Have the piers tilted?
7. Is there any cracking of the piers (columns, crossbeams, bracing)?
8. Do the bearings appear shifted?
9. Do the bearings show any damage?
10. Do the concrete box girders appear shifted?
11. Is there any cracking of the concrete box girders?
12. Are there any utilities damaged?
13. Is there any vertical or horizontal misalignment of the roadway/railing profile?
14. Do the deck joint openings appear excessive?
15. Is there a vertical or horizontal displacement of joints?

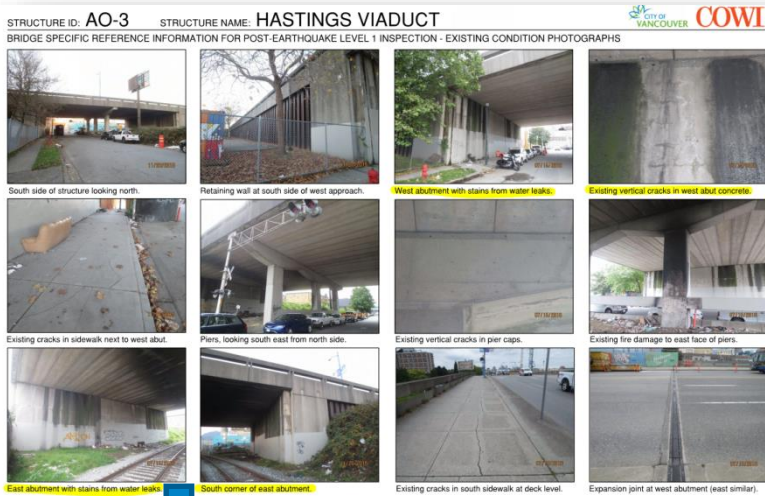
NOT APPLICABLE TO THIS STRUCTURE: 12

Question

Location

Flip Sheet

- Level 1 Evaluation Work Flow for Viaduct A:



West abutment with stains from water leaks.



Existing vertical cracks in west abut concrete.



East abutment with stains from water leaks.



South corner of east abutment.

Review existing photos of actual abutments and pre-existing condition



Return to Evaluation Sheet

- Level 1 Evaluation Work Flow for Hastings Viaduct:

Sig. Diagonal Cracks are present at East Abutment

	YES	NO	NOT APPLICABLE	NOT ACCESSIBLE	PICTURES TAKEN ? (See Note 1)	COMMENTS
4. Have the abutments tilted and/or experienced a significant loss of soil underneath?	Y	N	NA	X		
5. Is there any cracking in the abutments?	Y	N	NA	X		Sig. Diagonal Cracks at E.Abutment
6. Have the piers tilted?	Y	N	NA	X		

Proceed with evaluation of other structural elements

4. Status of Bridge

CONCLUDED DISPOSITION OF BRIDGE (RECOMMENDATION)	OPEN / CLOSED
BRIDGE TAGGED ACCORDINGLY?	YES / NO
BRIDGE CLOSURE IN PLACE	YES / NO

Seismic Performance Drawing Template

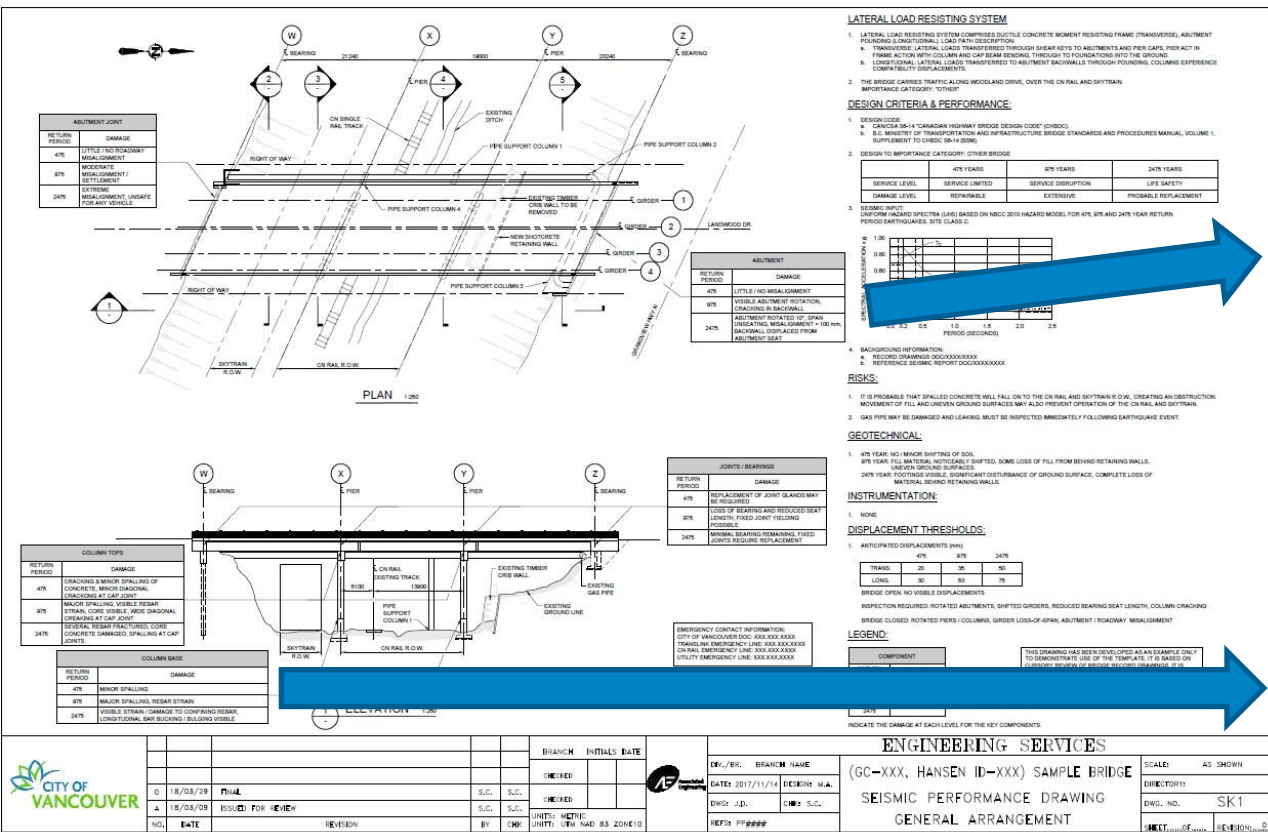
- Assist owners & inform responders/engineers
- Document design criteria/ philosophy
- Identify site specific requirements

Abutment

Return Period	Damage
475	Little / no misalignment
975	Visible abutment rotation / cracking in backwall
2475	Abutment rotated 10deg, span unseating, misalignment > 100mm

Column Base

Return Period	Damage
475	Minor spalling
975	Major spalling , rebar strain
2475	Visible strain, damage to confining rebar, longitudinal bar buckling, bulging visible



Future Improvements:

- Standardized photo library of typical damage states
- Guidance on what states indicate an open, closed or limited access structure
- Decision tree logic for specific damage states

Column Base		
Return Period	Damage	Reference Photo
475	Minor spalling	C##1
975	Major spalling , rebar strain	C##2
2475	Visible strain, damage to confining rebar, longitudinal bar buckling, bulging visible	C##3



Thank - You