PORT MANN/HIGHWAY 1 IMPROVEMENT PROJECT - ONSHORE WORKS

Hatch Mott MacDonald

MMM GROUP

CANADIAN CONSULTING engineer

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA
ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS | CANADA

Canadian Consulting Engineering Awards 2014

Submitted by:
Hatch Mott MacDonald
Suite 1000, 1066 West Hastings Street, Vancouver, BC V6E 3X2
T: 604.629.1736 | F: 604.639.1191
www.hatchmott.com

CONFIRMATION RECEIPT OF OFFICIAL ENTRY FORM/PROJECT OUTLINE

Hatch Mott MacDonald

MMM GROUP

Landscaping and Restoration Plantings

CONFIRMATION RECEIPT OF OFFICIAL ENTRY FORM/PROJECT OUTLINE

Grandview Highway

ENTRY CONSENT FORM

Hatch Mott MacDonald

MMM GROUP

160th Street Interchange

ENTRY CONSENT FORM

Landscaped Region North of Highway 1

Hatch Mott MacDonald

MMM GROUP

Highway 1/Lougheed Highway

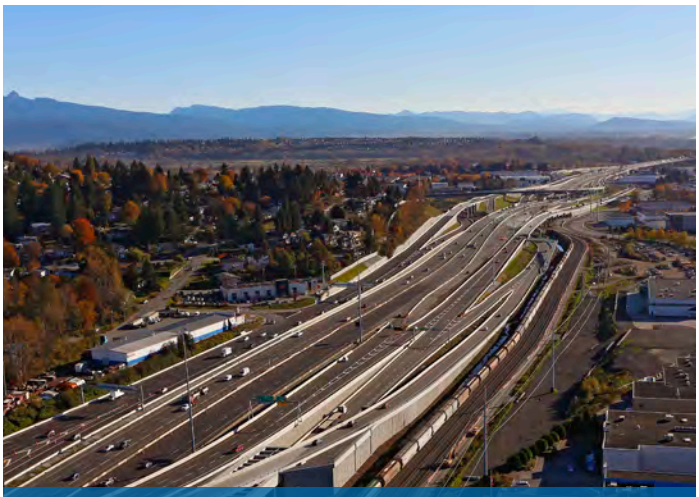
FULL PROJECT DESCRIPTION

FULL PROJECT DESCRIPTION

Toll Gantry

EXECUTIVE SUMMARY

Trans-Canada Highway 1 between Vancouver and Langley, British Columbia, is Metro Vancouver's busiest transportation corridor. The highway, with its many interchanges and connections into the region's communities, services daily commuters and commercial truck traffic, along with provincial and international travellers.



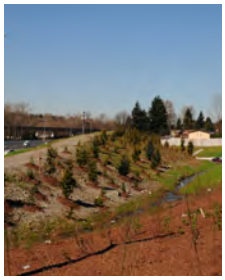
The Project corridor ran parallel to and intersected active railways and every type of utility, including electrical, lighting, fibre optic, gas, oil, drainage, and municipal services.

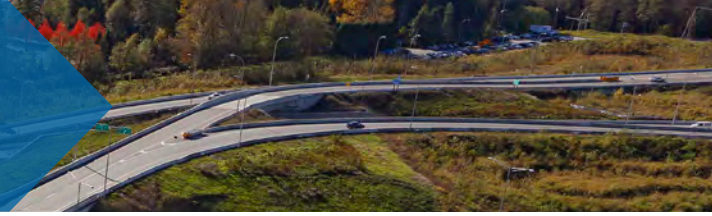
The Province of British Columbia established the Gateway Program in an effort to address congestion along the highway, as well as the region's expanding communities and growing trade networks. A key element of the Gateway Program was the Port Mann/Highway 1 Improvement (PMH1) Project: a $2.5-billion, 37-km upgrade to the highway. The Project was procured as a design-build and the largest transportation infrastructure project in British Columbia's history.

Hatch Mott MacDonald (HMM) and MMM Group formed a joint venture, H5M, to design the Project's $1.6-billion onshore works over an aggressive, five-year, fast-tracked, design and construction period. As the principal design consultants for the onshore works, HMM and MMM Group led the overall design effort with the support of 13 other local consultants.

The Project's onshore works were a masterwork of engineering design and delivery within a complex, urban environment. H5M overcame a series of complex project challenges, from confronting variable soil conditions and strict environmental obligations, to integrating the permanent designs with over 300 customized detour plans within a constrained and heavily utilized corridor. The team implemented a number of technical "firsts" for a project of this magnitude, such as developing the surface works, corridors, utilities, and drainage using 3D modelling and Building Information Management (BIM) methodologies.

By successfully completing this massive design effort, the H5M team enabled the Province and contractor to meet Toll Commencement by December 2012.





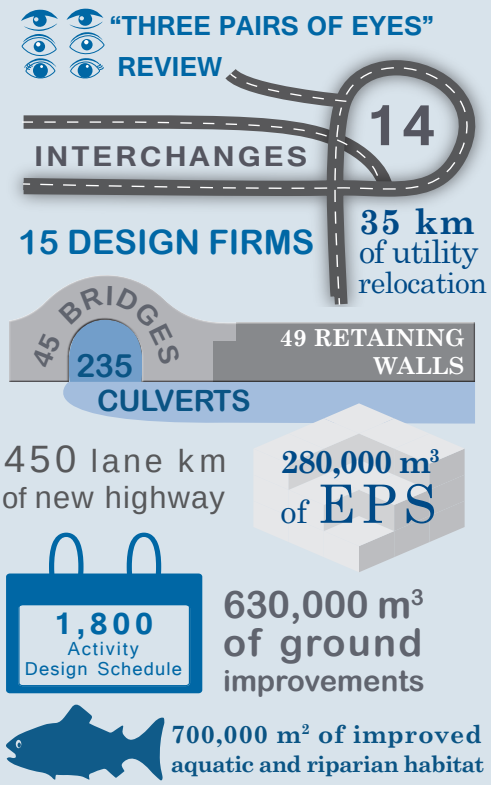
Project Highlights

The PMH1 Project was envisioned to be transformative. With the right combination of high-calibre management, design, and construction expertise, Trans-Canada Highway 1 would become the reliable, multi-modal transportation corridor needed for transit and commercial vehicles, as well as for Metro Vancouver's 2.2 million residents and the additional 1 million people expected to live in the region over the next 30 years.

Project management

The project management demands for a project of this magnitude were significant. HMM and MMM Group, as the H5M design joint venture, led the design for the $1.6-billion onshore works component—nearly 60 percent of the Project's overall cost. To keep the design work progressing, H5M team implemented systems that enabled the team to design and produce nearly 12,000 Issued for Construction (IFC) drawings in just over three years. At its peak, the H5M design team boasted over 250 team members logging in more than 1.1 million person hours of work since design commencement.

PROJECT FACTS



Building an integrated team

H5M took a proactive project management approach from the beginning. The 15 design firms and the contractor co-located in a single project office and adopted an integrated, "one-team" project philosophy. The overall schedule, technical details, and quality management took on a unified approach, and the decision to co-locate the entire team meant that design reviews and task force meetings were open and frequent, scope change discussions were regular, and that each member of the design team understood the contractor's priority areas.

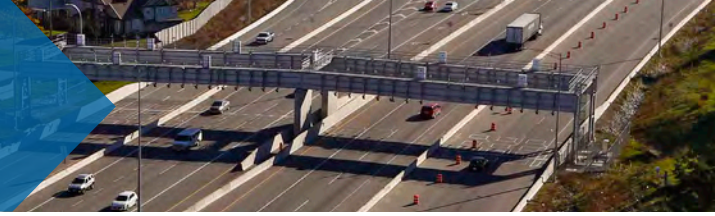
Design team members also co-located at site offices situated along the Project corridor for most of the construction phase. This two-way approach to co-location enabled the H5M design team to respond quickly and efficiently to issues from the field, collaborating with field engineers to anticipate the challenges that were inevitable, given the complex, urban nature of the corridor.

The dedication, trust, and teamwork from engineers with different skills and from different companies delivered the comprehensive and integrated designs needed to build this complex, arterial transportation corridor serving Vancouver and its nearby communities. H5M actively engaged the contractor and the owner, Transportation Infrastructure Corporation (TI Corp), early in the design process, using regular task force meetings that invited open discussion and collaboration.

"B.C.'s consulting engineers ensure the success of our highway, road and bridge construction projects and keeping our transportation network safe and efficient. H5M had a monumental task meeting the many, significant challenges of the Port Mann/Highway 1 Cape Horn Interchange project. With an innovative approach, the company not only met, but exceeded the ministry's expectations for the project.
Congratulations to H5M…for their outstanding work."

Todd Stone | Minister of Transportation and Infrastructure

TECHNICAL INNOVATION AND COMPLEXITY



Establishing project management systems

The PMH1 Project was under an aggressive schedule: the project was awarded in August 2008, with Toll Commencement achieved in December 2012. This meant that 37 km of lane improvements, 14 interchange replacements, and 45 new structures making up the onshore component needed to be designed and constructed in anticipation of this project milestone.

H5M developed a comprehensive design management plan to establish a framework for the thousands of design submittal packages that were reviewed, checked, and issued. The result was a four-stage design submittal process that allowed for inter-disciplinary reviews to integrate the requirements and constraints of each discipline into the design. This framework then set the foundation for a 1,800-activity design schedule that covered all design packages.

Quality was maintained under a "three pairs of eyes" review for all deliverables, and with design coordinators assigned to both geographic and technical areas.

Spanning the challenges

Project challenges came in all forms. When the H5M team was not combatting the variable soils or developing designs to fast-track construction in the highly constrained corridor, the team was meeting stringent, four-level, seismic performance requirements or designing many of the highway and drainage packages in a 3D environment—a design philosophy still in its infancy at the time. This was all done while keeping the contractor and owner's key milestones.

Project Milestones

	First Preload/ Surcharge Placed	500th IFC Drawing Submitted First Bridge Pile Installed	5,000th Drawing Submitted	10,000th Drawing Submitted	Toll Commencement Substantial Completion - Eastern Segment	Last Girder Lifted	Substantial Completion - Western Segment
	MAR 2009	AUG 2009	APR 2010	FEB 2011	DEC 2012	AUG 2013	DEC 2013
AUG 2008	JUN 2009	DEC 2009	JUN 2010	JUN 2011	APR 2013	SEP 2013	
Award of Project	First IFC Package Submitted	First Girder Lifted	First EPS Blocks Laid	Base Design Complete	Last Bridge Pile Installed	Last Preload/ Surcharge Placed	

TECHNICAL INNOVATION AND COMPLEXITY

Improving geotechnical performance

The alignment for Trans-Canada Highway 1 was selected in the 1960s, purposefully placed in areas of compressible ground. Better ground was reserved for commercial and residential developments, which left the H5M team to provide design solutions that considered compressible deltaic sediments (up to 5 m of near-surface peat), sensitive marine clays, variable glacial deposits, and potentially liquefiable sands. Given the placement of the orginal alignment, our team encountered highly variable soils on either side of the highway.

The Project required 280,000 m³ of EPS, believed to be the largest volume of EPS used on a single North American project.

The team developed a variety of solutions to meet the complex challenges created by the variable ground conditions along the corridor. In addition to over 200 preloads and surcharges (requiring over 500,000 m³ of fill), 25 lightweight expanded polystyrene (EPS) embankments were designed to mitigate expensive deep ground improvements and reduce post-construction settlement. This required approximately 280,000 m³ of EPS, believed to be the largest volume of EPS used on a single North American project. At three interchanges, where there were highly sensitive marine clays and compressible soils, the team designed replacement bridge approaches with a combination bridge and timber-pile-and-EPS solution that successfully reduced the new bridge lengths by nearly two-thirds.

Addressing the multi-level seismic performance criteria required 625,000 m³ of ground improvement, including stone columns and compaction piles to treat potentially liquefiable soils. A Cyclic Direct Simple Shear (DSS) Testing Laboratory program on the silty sands confirmed increased resistance to liquefaction, when compared to routine techniques, resulted in the reduction of ground improvement in certain areas. The team also undertook Dynamic Numerical modelling (FLAC) to simulate liquefaction. Interactions with existing infrastructure were another careful design consideration; further information is provided on page 9 on this important design feature.

Meeting seismic objectives

All structures on the Project met stringent requirements with regards to both analysis and design.

The Province mandated that an onerous, performance-based design (PBD) approach be taken for the seismic response of all bridges, walls, and embankments. These stringent requirements, with regards to both analysis and design, surpassed the requirements outlined by the current design standards of the jurisdiction. This made the PMH1 Project one of the first large-scale B.C. Ministry of Transportation and Infrastructure projects to adopt PBD principles; much of the PBD philosophy developed and applied to the PMH1 Project is currently under review for inclusion in the next version of the Canadian Highway Bridge Design Code (CHBDC).

H5M developed analytical models for bridges, walls, and embankments that simulated earthquakes with four different return period events, as well as a subduction event unique to British Columbia's coast. All onshore structures had specified performance objectives for both limited service after moderate events and significantly limited service after major events; corresponding strain-based criteria were developed and adopted in the design. No loss of span was allowed for extreme events.

The H5M seismic designs used a combination of analytical tools, such as multi-modal response spectra, static non-linear "pushovers," and dynamic, non-linear time history analyses. The team also established preferred load path fuses for each structure and detailed structural components for ductility and resilience. All other elements were then sized using the principles of capacity-protected design.

TECHNICAL INNOVATION AND COMPLEXITY

Designing within a complex urban environment

Trans-Canada Highway 1 is a dense, busy highway corridor. Over 125,000 vehicles use the highway to travel within Metro Vancouver or to cross the Fraser River each day.

This environment created a congested corridor for the H5M team to work within. The PMH1 Project traversed network links and municipal crossings, as well as multiple railway and public transit lines. The corridor ran parallel to and regularly intersected every utility: electrical, lighting, fibre optic, gas, oil, drainage, and municipal services.

The PMH1 Project was designed and built through a dense, highly constrained urban corridor.

Successfully preparing designs within this complex, urban context required H5M, the contractor, and numerous stakeholders to take an integrated and collaborative approach. H5M proactively communicated with more than a dozen third-party utility stakeholders for the more than 100 individual utility relocation and protection designs developed for the Project. Limited lane closures and little tolerance for delays to the public called for the permanent designs to be integrated with over 300 traffic detours designed by the contractor. Understanding and participating in reviews of the detour plans enabled the H5M team to develop innovative staging concepts that used temporary structures and re-purposed existing components to minimize traffic disruption through the complex staging and construction period.

Current data confirms that travel time between Vancouver and Langley has been reduced by 50 percent.

"Without you and your team joining us in the segment 2 complex and becoming integral to the planning and execution efforts, we would probably not have achieved the ATC scope of work. Please pass on my thanks to your entire design and DRDC teams for the dedicated and tireless effort put forth over the last two years and for their willingness to support operations at all hours of the day and night no matter what day of the week work took place. This is the true definition of a team effort…"

Carlo Anamasi Jr | Kiewit-Flatiron Project Sponsor

Visualizing with BIM and Autodesk Civil 3D

The Project's complex onshore works called for 3D civil modelling and design tools to be adopted. When the Project began in 2008, each of these tools represented a significant leap forward in civil engineering design delivery in North America. Building information management (BIM) methodologies proved to be invaluable to managing the Project's cross-discipline design coordination activities. However, H5M had no BIM guidelines or best practices to help meet the demands of this complex, design-build highway project—H5M developed these on its own.

H5M selected Autodesk Civil 3D as the main design software for surfaces, corridors, utilities, and drainage. The Civil 3D package included BIM tools that assisted with the team's cross-discipline design coordination needs. Autodesk Navisworks served as a supplemental visual tool for critical locations, and was used during integrated planning meetings with the contractor. By integrating each discipline's designs, the project team could better appreciate the overall design, and identify and resolve any inter-disciplinary conflicts or constructability issues ahead of time.

Coordinating a team of 15 design firms was already a massive undertaking, especially when developing and mastering new software and workflow learning curves. The H5M team committed to start-up training and best practices by nominating CAD/BIM Managers for each discipline. These managers were able to work closely with design leads, the project controls team, the document control team, and the contractor to streamline data management, quality control, change control, and schedules. H5M introduced new data management software and processes, dedicated systems, and a collaborative, integrated team structure to help progress the design and drawing development in a systematic way.

Deploying intelligent transportation systems

Intelligent transportation systems (ITS) were deployed widely across the PMH1 Project to help advance regional transportation initiatives. The systems have improved the monitoring of freeway traffic conditions and have continued to help manage incidents along the entire highway corridor.

New CCTV cameras have been providing real-time monitoring of highway and ramp traffic to the Regional Transportation Management Centre (RTMC), as well as images for the public relayed through the Ministry's DriveBC website. In addition, radar technology has been measuring vehicle speed, traffic density, and vehicle types along the corridor. Seismic monitoring instrumentation systems have been installed on and near interchange structures to provide the Province, other agencies, the Earthquake Engineering Research Facility at UBC, and the Geoscience Centre in Sidney, B.C., with real-time ground motion data and structural health data during and after seismic events.

The H5M team also managed the installation of a new, automated lane control system for the Cassiar Tunnel's expansion from four to six lanes. Since then, the new system has offered more advanced control capabilities and direct control from the RTMC. The emergency tunnel closure system for the ramp tunnel at the Cape Horn Interchange has also been designed to permit the safe closure of the tunnel by remote control during emergency events.

The ITS systems have been connected to a new fibre optic network forming part of the Ministry's major fibre optic deployment initiatives across Metro Vancouver. All three Local Operations Centres are now connected back to the RTMC.

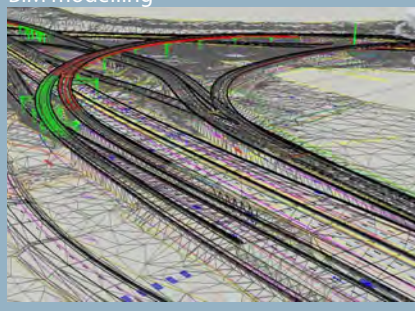
The Evolution of the Cape Horn Interchange

THE BEGINNING

Before

THE MIDDLE

BIM modelling



BIM modelling

During construction

THE END

After

SOCIAL, ECONOMIC, AND ENVIRONMENTAL BENEFITS

Stimulating the local markets

We are proud that PMH1 Project's onshore works were designed by local Metro Vancouver engineering teams. Overall, the Project encouraged growth in the local technical and trades job markets, and allowed the H5M design team to receive the unparalleled experience of working in familiar neighbourhoods and on one of British Columbia's most complex infrastructure projects. More than 250 team members logging in more than 1.1 million hours of work helped guide the Project through to completion. As well, the team's design approach advanced highway engineering into the three-dimensional realm; by using BIM methodologies and Autodesk Civil 3D, H5M helped the industry gain momentum in this important facet of design development.

The Gateway Program's transportation network improvements have facilitated local economic growth by moving goods, people, and transit safely and efficiently through the region. As a key component of the Gateway Program, the PMH1 Project solidified Metro Vancouver's position as a strategic provincial and national trade centre. The region's major ports are now better connected with other major transportation corridors and key business centres, enhancing Metro Vancouver's ability to manage the enormous increase in Asia-Pacific trade.

A lasting legacy of the PMH1 Project has been its showcase of West Coast flavour. The landscaping design has featured local plant, shrub, and tree species, and has paid special attention to the seasonal character of highway. Species and treatments were varied to create long-term interest and colour for travellers. Woody plants, vegetated surfaces, and textured wall finishes have also enlivened the highway's infrastructure with detail and visual appeal.

Restoring habitats and improving air and water quality

The H5M team maintained environmental stewardship as a core Project value, and developed designs in consultation with First Nations, the Department of Fisheries and Oceans, and municipal, provincial, and federal government agencies. First Nations participated in information sessions and site visits to potential compensation sites, and provided comments that were considered in the subsequent designs.

The environmental design provided nearly 200,000 m^2 of aquatic habitat and 512,000 m^2 of riparian habitat. Thanks to the care and attention put into these designs, salmon returned to spawn in Still Creek for the first time in 80 years.

The environmental design improved fisheries habitats with compensation areas and wetlands, and provided nearly 200,000 m^2 of aquatic habitat and 512,000 m^2 of riparian habitat. H5M also incorporated refuge areas to protect young fish from high flows, and the Port Mann pump station was retrofitted with fish-friendly pumps. Fish passages through local streams received 30 new culvert designs that replicated the natural channels underneath Highway 1. Thanks to the care and attention put into H5M's environmental designs, salmon returned to spawn in Still Creek for the first time in 80 years.

The expanded wetlands design enhanced habitats for not only young Coho and Chinook salmon, but also the amphibians, small mammals, and other native wildlife living in the area. Special care was given to protect habitats for sensitive species, such as the Oregon forest snail, the Pacific water shrew, and the red-legged frog. Invasive plant species were removed, and diverse native plant species were reintroduced through the Project to increase habitat complexity. H5M's compensation designs also included avian perches to offer natural habitats for birds.

Our designs improved long-term water quality of highway runoff to benefit the environment for future generations. Forty-six oil-sediment separators, 11 water quality ponds, and dozens of other water quality measures—such as bio-swales, infiltration trenches, and grassed filter strips—were installed to help treat stormwater runoff from the pavement surface.

The Project increased high-occupancy vehicle (HOV) lanes, improved travel times, and lessened idling vehicles, which has continued to benefit the region's long-term air quality. H5M reduced waste disposal caused by the Project by reusing asphalt millings during paving or by re-purposing demolished bridge decks as inert embankment fill material where suitable.

MEETING THE CLIENT'S NEEDS

Achieving the vision

The Province of British Columbia's Gateway Program was established to address growing congestion, expanding populations, and multimodal connectivity throughout the region. As part of this program, the PMH1 Project's goals were to reduce congestion and travel times, improve safety and accessibility, facilitate expanded transit service, and expand the transportation network to accommodate high-occupancy vehicles, cyclists, and pedestrians.

H5M met these goals by producing designs that re-envisioned the current highway conditions: 37 km of widened highway reduced travel times by up to 50 percent, 14 replaced interchanges relieved congestion, improved sightlines increased highway safety, and pedestrian overpasses, multi-use pathways, and 30 km HOV lanes created a unique, multimodal transportation network. Major ports have improved connections with other major transportation corridors and key business centres in Metro Vancouver, which has enhanced the region's ability to manage increasing Asia-Pacific trade. The Project's final design reflected the fine balance needed between transit, road, and bridge improvements to keep the region liveable and the economy strong.

The end result was the owner's vision of Trans-Canada Highway 1 transformed into an effective, efficient transportation corridor. Transit and commercial vehicles, as well as Metro Vancouver's 2,200,000 residents and the additional 1,000,000 people expected over the next 30 years, now enjoy the improvements made to this key arterial corridor that enhance the region's ability to meet future growth and expansions in national and international trade.

PROJECT SUCCESSES

IMPROVED CONNECTIONS
within and between communities

COMPLEX STAGED DESIGN & CONSTRUCTION
uninterrupted traffic flow

REDUCED CONGESTION & TRAVEL TIME
on Highway 1

ENHANCED TRANSIT CONNECTIVITY
across the Highway 1 corridor

EXPANDED HOV
cycling and pedestrian networks

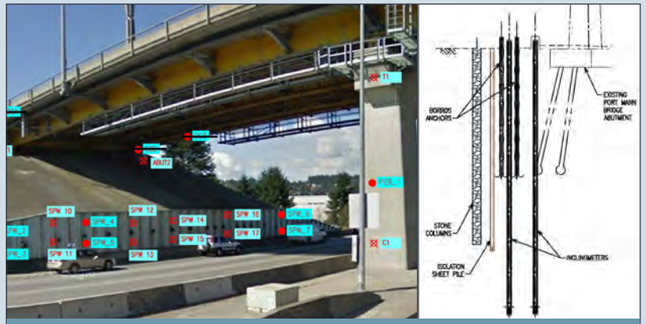
RELOCATION OF 1KM OF CANADIAN PACIFIC RAILWAY
in a congested urban environment

IMPROVED SAFETY
for vehicle operators and passengers, cyclists, and pedestrians

HABITAT RESTORATION
reintroduced adult salmon in Upper Still Creek culverts for the first time in 80 years

SEISMIC SAFETY
improved for lifeline and vital economic corridor

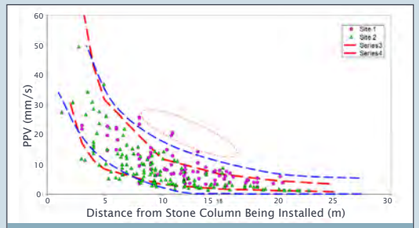
GROUND MOVEMENTS & CONSIDERATION OF EXISTING INFRASTRUCTURE



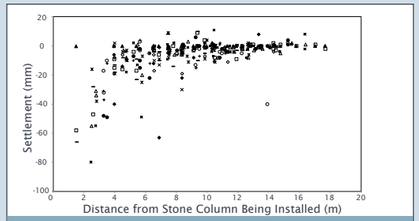
Monitoring of the Existing Port Mann Bridge West Abutment

NEW PORT MANN BRIDGE WEST ABUTMENT (STRUCTURE 8390)

The West Abutment (8390) for the new Fraser River Crossing is 10 lanes wide, 14m high and was constructed in two stages to maintain traffic over the exiting bridge. The new abutment needed to be built on/adjacent to the existing (old) bridge abutment without affecting the traffic on the old bridge. Therefore the ground improvement footprint in front of the embankment was limited. Hence the abutment was partially built with lightweight fill (EPS) to reduce the weight and inertial effects on the foundation. The EPS was also required because the schedule did not allow surcharging of the abutment prior to commencing the launch for the new bridge. Prior to paving, the abutment was monitored during the two year bridge construction period to confirm the settlement of the hybrid EPS/mineral fill scheme was acceptable and in-line with the predicted values.



Ground Vibration vs. Distance from Stone Column

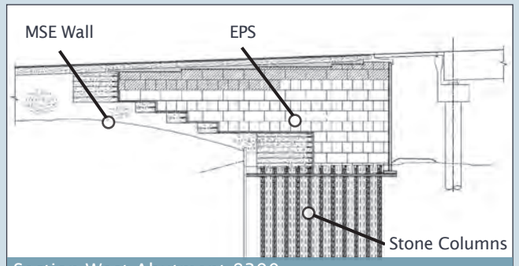


Ground Settlement vs. Distance from Stone Column

Stone columns for the new abutment 8390 were installed in close proximity (5-6 m) to the old Port Mann Bridge Abutment. The team undertook a test section to assess the potential impact with respect to ground movements and vibrations. This information was used to develop a protection monitoring scheme to safeguard the existing bridge and other infrastructure surrounding the project.

The west approach abutment was constructed on time without adversely affecting the adjacent exiting bridge and the settlement observed during construction was in reasonable agreement with that predicted.

Construction of New West Abutment 8390



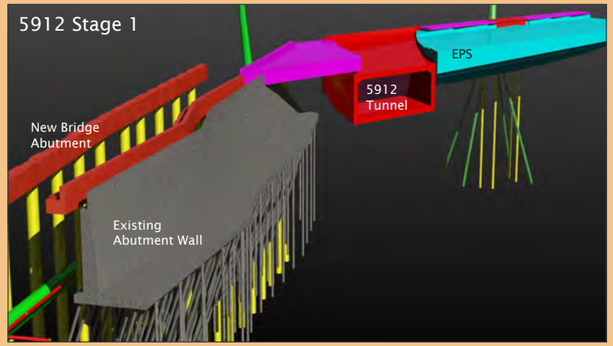
Section West Abutment 8390

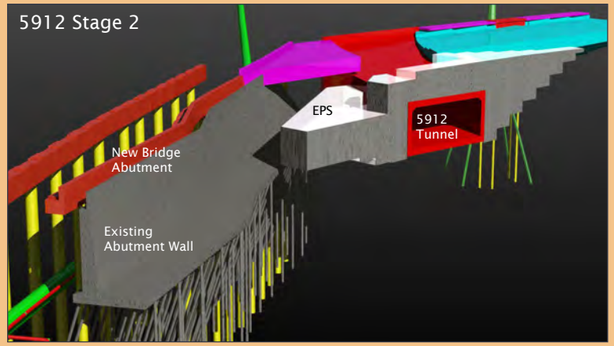
New Completed West Abutment 8390

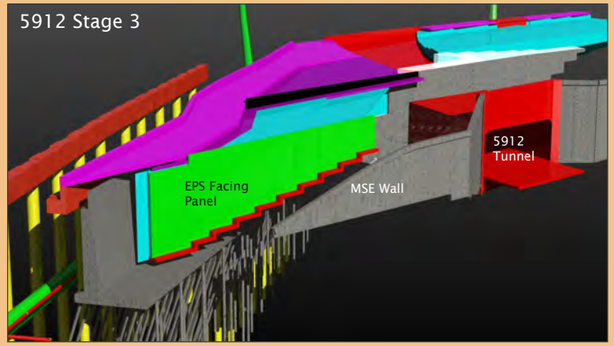
COMPLEX STAGING FOR THE CONSTRUCTION OF 5912

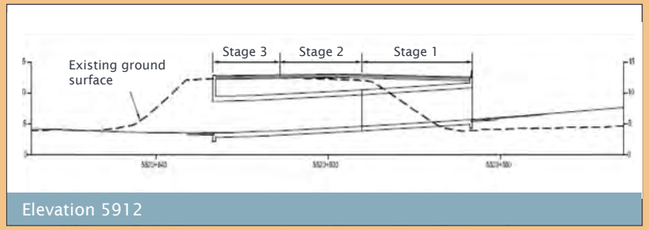
The evaluation of expected settlements and the staging process enabled the successful construction of the underpass in three stages, with one less stich pour than originally assumed.

Many of the structures had to be constructed in phases to facilitate the multi-stage detours required to maintain unrestricted operation of the highway. Underpass 5912 transverses HWY1 and was constructed in 3 stages in tandem with adjacent bridge 1627, crossing the CP rail corridor. Beneath the overpass the near surface soils included 1.9 to 3.4 m of fibrous peat and organic silt. Given the structure was to be constructed in three stages it was important to evaluate the expected ground displacement. Predicting the settlement required consideration of stage 1 being built on virgin soils (thereby initially requiring surcharging) and with the other two stages being constructed within the footprint of the existing embankment.

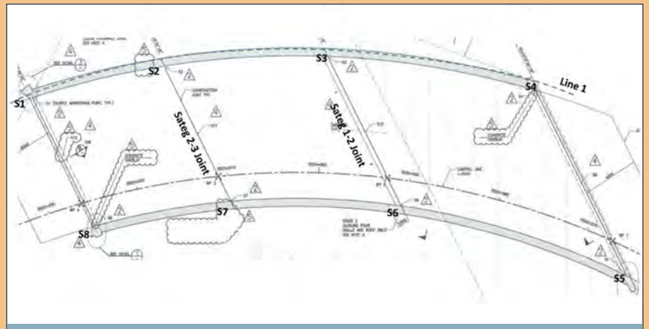




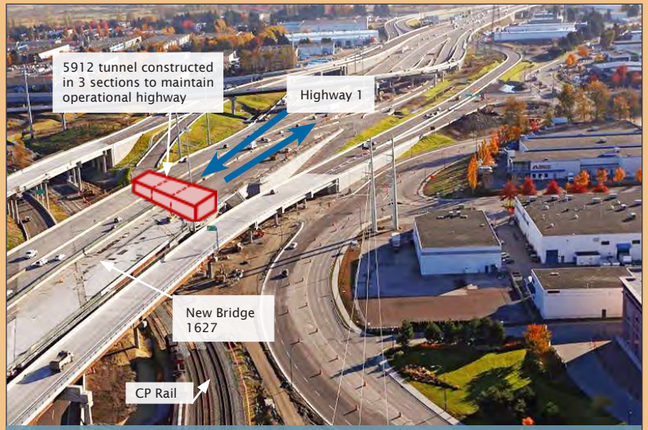




Elevation 5912



Plan 5912



Aerial view of 5912 Tunnel & Bridge 1627

APPENDIX A: PROJECT AWARDS

APPENDIX A: PROJECT AWARDS

Toll Gantry

Deputy Minister's Consulting Engineers Award (BC)

Design and Contract Preparation - Roads for the Cape Horn Interchange Project

ACEC-BC 2014 Lieutenant Governor's Award for Engineering Excellence

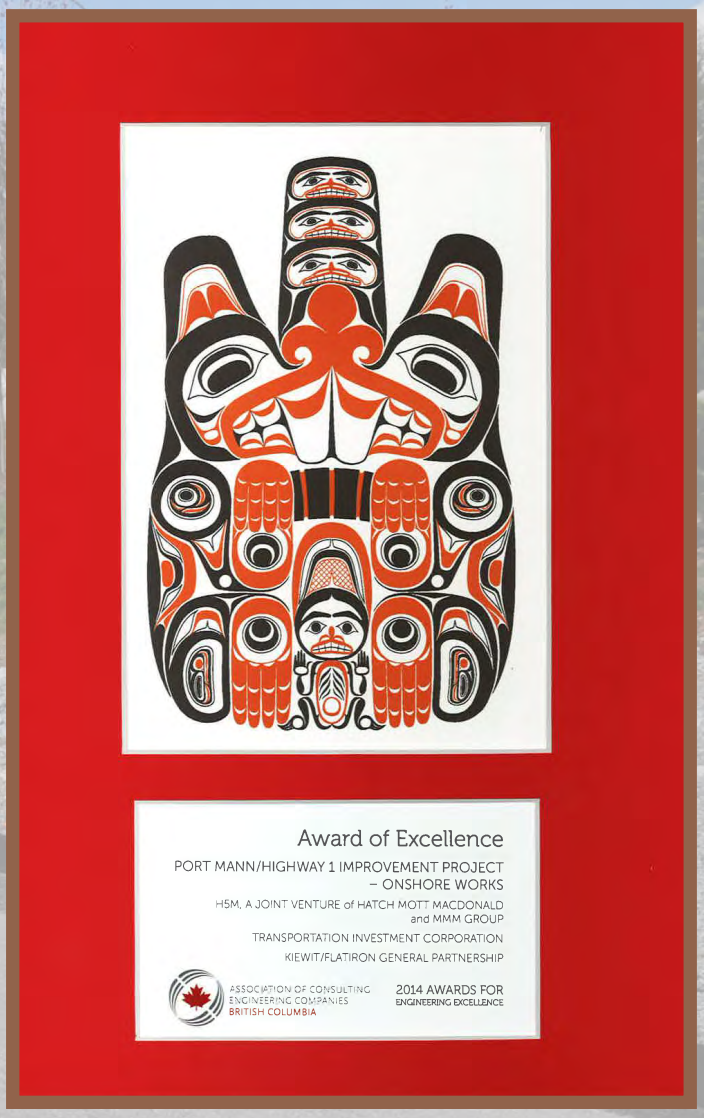
Port Mann/Highway 1 Improvement Project - Onshore Works

Hatch Mott MacDonald

MMM GROUP

ACEC-BC 2014 Award for Engineering Excellence

Port Mann/Highway 1 Improvement Project - Onshore Works



ACEC-BC 2014 Award for Engineering Excellence

Port Mann/Highway 1 Improvement Project - Onshore Works

Hatch Mott MacDonald

MMM GROUP

Cape Horn Interchange

APPENDIX B: PROJECT PHOTOGRAPHS

APPENDIX B: PROJECT PHOTOGRAPHS

This bridge is the longest onshore structure, measuring 574 m and connecting Lougheed Highway W/B to Highway 1 E/B. This picture shows a unique three-crane lift of the first section of this structure.

This picture, looking east along Highway 1 in Coquitlam, shows the dense urban corridor that the H5M team worked within to provide designs that could be constructed in stages.

Highway 1 at Boundary Road showing staged construction of Boundary Road Overpass and its associated approach embankments. The structure was designed to facilitate phased construction that allowed existing traffic to be maintained during construction.

When Cape Horn Interchange was under construction, various structures and highway alignments were designed to facilitate staged construction and to accommodate the continuity of existing traffic movements.

Ground improvement work included stone column installations, which formed part of an innovative load transfer platform system at the north end of Willingdon interchange.

New HOV off- and on- ramps at 156th Interchange connect to the improved transit system now operating from the Carvolth Transit Exchange in Langley that opened in December 2012. Photo kindly provided by TI Corp.

The reconfigured Cape Horn Interchange improves connectivity between Metro Vancouver communities.

The completed Fraser Heights bridge was designed to be constructed with a top-down technique to minimize disturbances to sensitive environmental marshland.