AECOM

M1 Canal Rehabilitation

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Project Overview

The M1 Canal is one of the most important water supply canals in Saskatchewan. Envisaged following the droughts in the 1930's and completed in the 1960's as part of the South Saskatchewan River Project, it now supports more than 55,000 acres of irrigated land; five storage reservoirs totalling 125,000 dam^3 in storage capacity and with valuable recreational areas; non-potable water supply for seven towns, villages, and resort communities; three potash mines, and; thirteen wildlife habitat and wetland projects.

Entering into the 21st century, the M1 Canal and its components were nearing the end of their service life and required major rehabilitation along with expanded capacity. The Saskatchewan Ministry of Agriculture initiated the rehabilitation program and later transferred ownership to the Water Security Agency because the province recognized it as a critical water source. AECOM's involvement first began in 2008 with a comprehensive condition assessment and asset management plan. This led into preliminary design in 2010 and subsequent permitting, detailed design, land acquisition, tendering, and construction services over a 10 year period.

The program involved the rehabilitation of the entire 22.5 kilometers of canal and associated structures. The ambitious undertaking presented significant capital investment and short construction timelines outside of the canal's normal operating season of May to September. The rehabilitation was completed as individual construction packages that were scoped to match the province's annual capital budget. The project required strict construction timelines to be met. Earthworks construction was undertaken in the autumn and in-canal works were completed by the end of the winter so that the canal was able to resume operation in the spring.

In 2021, the M1 Canal Rehabilitation was successfully completed in its entirety. This rehabilitation program involved lining the canal with an RPE liner and granular armour, widening the canal for increased capacity, and replacement, rehabilitation, or new installation of over 100 structures ranging from drain inlet culverts to check structures, cross-drains, and an emergency overflow structure. The project has reinstated the service life of the canal, upgraded to meet current and future flow demands, and enabled the future expansion of irrigation, industry, and mining.

Rehabilitated M1 Canal Reach 3A

1. Innovation

This project presented the first large-scale canal rehabilitation program undertaken in the province as well as one of the most significant water resources projects since construction of the Gardiner Dam that created Lake Diefenbaker. From the initiation of the program, our approach was driven by knowledge and experience proven in other jurisdictions. As the program progressed, the approach was continually refined and improved as best practices from projects in Southern Alberta were used as a basis and revised to best suit Saskatchewan conditions. In the beginning, engineering, construction contractors, trades, and suppliers were largely from outside of Saskatchewan since there was a limited canal and irrigation market established in Saskatchewan at the time. However, we quickly adapted and the project design and contract administration was predominately delivered by our team of local, Saskatchewan-based engineers. The capabilities of Saskatchewan-based contractors, trades, and suppliers developed and were involved in significant aspects of the construction program as the 10 year rehabilitation program progressed.

The design was completed by numerous engineering disciplines, including civil, hydrotechnical, structural, mechanical, electrical, instrumentation, and environmental. In addition, there were a number of other technical areas, including land acquisition, utility coordination, and environmental and regulatory permitting that all fell under the comprehensive scope that AECOM delivered from start to finish.

As the program progressed, the approach was continually refined and improved upon based upon the local conditions.

Protection of canal infrastructure

The M1 Canal is the most important supply canal in the province, and the protection of its infrastructure was paramount. Accordingly, numerous safeguards were implemented into the design.

The canal check structures are recognized as an important component to the infrastructure. The selection of the gates was a key consideration. The original radial gates, where flow passes beneath the gate, were replaced with overshot gates. Because flow passes over the gate, overshot gates are better suited to passing debris and flood flows with a comparatively smaller rise in water level.

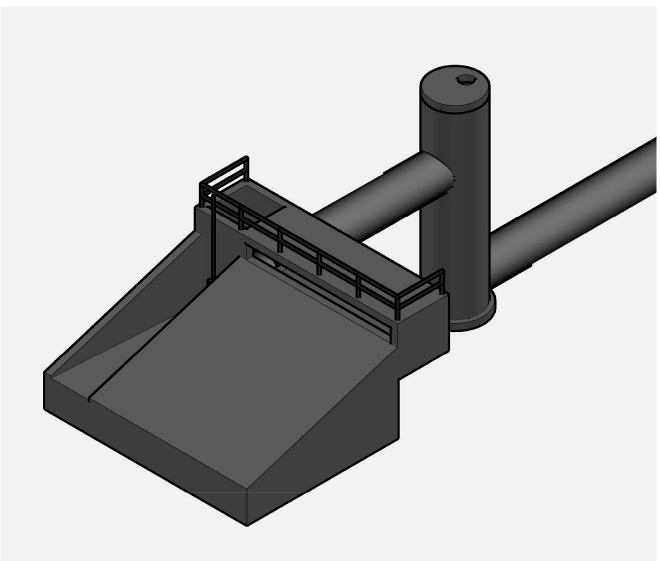
The check structures were designed with electric, fully automated operators with the provision for a future SCADA system for remote monitoring and control. The check structure controls were equipped with auto-dialers for alarms that would notify operations staff of the alarm conditions. In the event of a power failure, the gates can be powered by a standby generator or manually operated with a handwheel. A bulkhead was procured and is stored nearby so that it can be quickly used to isolate a bay of the check structure if a gate fails.

The original canal lacked a wasteway structure, which is required to waste surge flows from the canal to prevent possible overtopping. Although the canal is supplied

Check Structure M1-48

Check Station After Rehabilitation

by a pump station so that inlet flows are controlled, surge flows may result from inflow of runoff from intense rain events or the instantaneous shutdown of pumped turnouts due to power failure, which are both common events on the prairies and can often occur simultaneously. To handle the surge flows, a wasteway structure was designed where the canal crossed a deep creek valley. The wasteway was designed for a flow of 4.2 m³/s (15% of canal capacity) and consists of a 7.5 m long side weir set at 100 mm above the canal full supply level. Flow that passed over the side weir drains to a 1500 mm diameter pipe. A drop shaft energy dissipator structure was constructed to manage the nearly 6 m drop in elevation from the canal to the creek valley. A gated outlet in the wasteway structure was included to provide a means to dewater the canal.



Wasteway M1-23A (3D Rendering)

Modern irrigation technology

There has been significant technological evolution since the M1 Canal was originally constructed in the late 1960's. With the major rehabilitation program, considerations were made for upgrading the components to modern systems. The check structures were originally constructed for manual operation of the gate position with a handwheel. The new check structures included electrical controls that automatically set the gate levels based on either the canal flow or to maintain the desired water level. Compared to manual operation, this improves operator safety, eliminates manual operation, and provides almost immediate response to changing flow conditions.

All turnouts were replaced as part of the canal rehabilitation. The majority of the original turnouts supplied lateral canals that delivered supply to flood irrigation. Through advancement on the field scale of irrigation practices from flood irrigation to wheel move to pivots with low-pressure sprinklers, water use efficiency has significantly improved. This meant that, even with the expansion of irrigated acres delivered by a turnout, the design flows were often smaller than the original design flows. This allowed for an optimization of the turnout structure and piping that resulted in a lower-cost structure that serviced a larger area.

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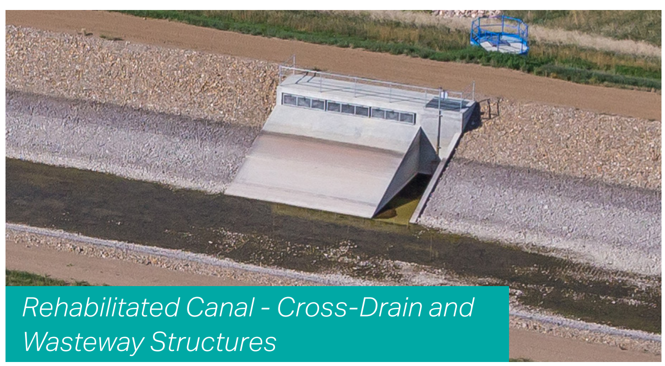

Rehabilitated Canal - Cross-Drain and Wasteway Structures

2. Complexity

The M1 Canal is a 22.5 km long canal that is filled from Lake Diefenbaker and empties to Broderick Reservoir. The canal is a main supply to a large irrigation district, five reservoirs, numerous communities and potash mines, and wildlife and wetland projects. The M1 Canal has been in operation for 50 years and was nearing the end of its service life. The canal had a reduced conveyance capacity caused by folds in the surface liner and had significant losses through seepage. The manually operated structures were outdated and required replacement and upgrades to improve operation and safety.

OBJECTIVES

Address Risk of Failure

One of the primary objectives for the project was to address the more imminent risks associated with public safety, potential loss of operation, and seepage. AECOM prepared the M1 Canal - Asset Management Plan prior to the initiation of the rehabilitation program, which categorized high priority structures based on the consequence of failure. Four large cross-drain culverts were identified as having the highest risk. Their failure would lead to catastrophic failure of the canal embankment, loss of supply to the downstream system, and significant consequence to off-site road and bridge infrastructure and public safety. To mitigate this risk, the cross-drain culverts were rehabilitated ahead of the full scale canal construction program.

Mitigate Economic and Environmental Inefficiencies

Another objective was to replace and rehabilitate the aging infrastructure, which included the canal liner, check structures, turnout structures, and drain inlets. Because the M1 Canal is filled from Lake Diefenbaker by pumping, seepage losses presented a monetary and environmental cost, resulting from water supply losses and saturated and saline conditions formed in adjacent farmland. The mitigation of the seepage losses by installation of an engineered lining system for the canal presents sound economic and environmental stewardship.

Enhance Safety

The canal structures were operated manually with handwheels, which was difficult and risky and required upgrades or replacement to improve ease of operation and worker safety.

Expand Capacity

The rehabilitation program for the M1 Canal would correct these deficiencies while also increasing the canal capacity. The canal capacity was increased by 50% from 18.4 m^3/s to 28 m^3/s to provide capacity for current demands and future expansion in irrigation, industry, and mining. This required significant earthworks to widen the canal from 6.1 m to 9.5 m.

Main Project Objectives:

- Upgrade critical canal infrastructure to mitigate risks and enhance safety
- Upgrade and modernize equipment, materials, and structures
- Increase conveyance capacity for current and future use
- Mitigate seepage to improve conveyance efficiency and reduce impact to adjacent farmland

M1 Canal - Canal Excavation

SOLUTIONS

Emergent Design and Foresight

A practical approach to design was used through every stage of the project. Efficiency of the project delivery was achieved through a standardized design that was applied and scaled as needed. The M1 Canal – Asset Management Plan prepared by AECOM, which reviewed and prioritized all the components for either replacement or rehabilitation, provided a framework for the preliminary and detailed design. A total of 140 structure replacements or rehabilitations were designed and included turnouts, drain inlets, cross-drains, check structures, bridges, an emergency wasteway structure, and a reservoir weir inlet structure.

The project was staged according to the length of canal rehabilitation that could be constructed within the annual capital budget while considering the entire system while designing the individual sections. This included irrigation turnout deliveries, which were designed to supply gravity canals or pumped pipelines and service a single irrigation pivot up to a district of multiple irrigation parcels. Early structure design consisted of corrugated steel pipe (CSP) turnout and pumpwell, and this progressed into selecting more robust materials such as precast concrete structures and High Density Polyethylene (HDPE) piping. The metal fabrications at the turnouts, such as grating and handrails, included standard sizes and readily available materials. The design of these materials became standardized with an eye to efficiency of fabrication, reduced cost, and using local supplier skills and availability.

Although the structures were nearly 50 years old, close consideration was given to the reuse and modification of existing structures where possible. For example, the structural concrete at the check structures, reservoir inlet structure, and bridges was determined suitable to be retained with modifications. Additionally, the large cross-drain culverts under high embankments were rehabilitated with Cured-In-Place Plastic (CIPP) lining. Compared to replacement, rehabilitation with modifications presented a number of key advantages such as reduced construction cost, shorter construction duration, and less impact to the public and to the environment. This approach was founded on thorough structural and hydraulic assessments to confirm the modifications met the objective of increased canal capacity. For example, the location and shape of the original basin blocks in the check structures were determined to provide suitable energy dissipation for the new overshot gate configuration and the chute walls at the existing reservoir inlet structure were raised to contain the flow depth and overspray of the greater design flow.

By the Numbers

19 bridges

6 check structures

7 cross-drains

63 drain inlets

43 turnouts

1 wasteway

1 reservoir inlet structure

Modernization of Equipment and Materials

Most of the existing structures were found to be outdated with manually operated controls and inadequate safety measures. Advancements in technology and more stringent safety regulations were incorporated into the assessment of the improvements. In particular, the overshot gates replaced manually operated radial gates at each of the six check structure. The new gates were fitted with electrically driven gate operators that automatically move the gate position based on either the canal flow or to maintain a set water level. Additionally, provisions for a SCADA system were incorporated to allow for future remote monitoring and control. Digital flow meters were installed for more accurate flow monitoring, which replaced the previous method of counting turns of the handwheel. Materials were sourced that considered the required service life. A Reinforced Polyethylene (RPE) liner with granular armour was installed to provide seepage control. Selection of the liner considered materials that were commercially available and consisted of various materials and grades such as fabricated geomembrane PVC, RPE, bituminous geomembrane, and geo-composite surface liner. The RPE liner was selected as the preferred material considering cost, service life, and cold weather workability.

Trenchless Technologies

The M1 Canal - Asset Management Plan identified four large cross-drain culverts that required immediate repair or replacement. These cross-drain culverts were located on creeks that passed well below the canal and included pipe sizes of up to 1800 mm diameter and lengths of up to 100 m. Replacement by open cut was found to be too costly and presented additional risks to the canal embankment. Alternatively, several trenchless pipeline technologies were considered including CIPP, Glassfibre Reinforced Plastic (GRP) segmented liners, slip lining with steel pipe and tunnelling and jacking with concrete pipe. Competitive construction bids were obtained for different alternatives, and the CIPP alternative was determined to have the least cost at approximately 50 – 60% of the cost for steel pipe slip lining and 19% of concrete pipe jacking. The CIPP lining provided full structural pipe rehabilitation with limited disruption and risk; however, the diameter of the cross-drains were near the upper limit for this technology and required careful design and construction considerations. Construction occurred during February and March of 2011 to take advantage of frozen ground to support heavy equipment and when water inflow was at a seasonal minimum.

Construction Complexities

The M1 Canal normally operates annually from May to September to provide water supply to the various downstream users and to fill reservoirs with sufficient capacity to supply communities and potash mines through winter. As a result, construction occurred in autumn following the end of the canal's operating season. The timing of earthworks construction presented significant challenges as the canal excavation material was saturated and the opportunity for drying and conditioning the material was limited and required practical technical specifications be developed and careful monitoring of the work by experienced AECOM field engineers.

Given the complexity and scale of construction and the importance of meeting the contract deadlines in a compressed and challenging construction period, a contractor prequalification stage was implemented prior to annual tendering of the construction contract. This process selected contractors that had the knowledge, experience, and resources to successfully complete the construction in accordance with the contract documents and meet the important milestone dates so that the canal would be able to begin operation on schedule in the following season.

Application of Design Tools

Numerous design tools were used to aid the design and construction. A comprehensive 1D model of the M1 Canal was developed in HEC-RAS, which is a software used to model open channel flow and delineate water surface profiles. The model augmented traditional design methods and incorporated the geometry of the canal transitions through the bridges and the inline check structures with the full range of gate positions. This model was used to quantify the cumulative headloss of the individual canal structures and delineate the water surface profile, which determined the design water levels at the check structures and turnouts. Earthworks modelling was completed using Section 3D and later Civil 3D. The design surfaces were provided to the construction contractor to load into their earthworks equipment for GPS guidance and control. Topographic and bathymetric survey was conducted using GPS and total station. At the conclusion of the project, a GIS asset management system was created using Arc GIS.

Protection of Oil Pipeline Infrastructure

The M1 Canal passed over a significant corridor that consisted of eight individual oil pipelines. The pipelines are a vital oil and gas supply from Canada to the United States and represented one of the highest construction risks on the project. Any impact to the pipelines would have significant economic and environmental consequences for the contractor and WSA.

The pipelines varied in age from 1950 (prior to the canal construction) to 2017 and the shallowest pipe was at a depth of 0.50 m below the canal. Lowering the pipelines had a prohibitively high construction cost and would be especially challenging to construct while maintaining pipeline operation. Alternatively, a 108 m long slab of reinforced concrete in the bottom of the canal over the pipelines was recommended to protect the pipelines. The slab was meant to provide a hard surface along the canal bottom to protect against accidental excavation in the future.

The need for pipeline protection required key considerations in the design and included specific construction protocols to be incorporated into the contract requirements that mitigated the risk profile for the entire project team. Coordination and approval by the oil pipeline owners was recognized as a critical path item, and significant discussions were held early on. The coordination ultimately turned into a partnership with the involved oil and gas companies as we progressed from design to construction phases, and the potential impact to construction was mitigated.

3. Social & Economic Benefits

SOCIAL SUSTAINABILITY

Prepared for economic development

The additional capacity of the canal is presently available for when the expansion in irrigation, industry, and mining requires it. This addresses a key prerequisite to development – the need for adequate water supply. In fact, new irrigation development has already occurred in the immediate area. The impacts of these expanded industries are well known to promote the development of service centres of suppliers and trades, which sustain vibrant communities in the surrounding area.

Strengthening our capabilities

With this being the first large-scale canal and irrigation project completed in the province in recent years, there was tremendous growth of knowledge and experience in AECOM's local engineering team. In addition, our work with WSA allowed for expanded capabilities and experience for local construction contractors, suppliers such as metal fabricators and aggregate suppliers, and trades. This sets the stage for significant involvement of local companies in the province's ambitious plans for irrigation expansion around Lake Diefenbaker and in other provinces.

ECONOMIC

Foster irrigation, industrial, and mining development

The economic impacts of the canal rehabilitation can be measured on both the local and greater provincial footprint. Combined with the rehabilitation objective, the project was to increase the canal capacity by 50% to support irrigation industry, and mining, which are the province's largest economic sectors. As evidence of the importance of this project, one of the province's largest private investments, the BHP Jansen Potash Mine, is dependent on the water that is delivered by the expanded capacity of the M1 Canal. In addition, with expansion in irrigation capacity, increased and more reliable agricultural production, introduction of higher-value crops, and value-added processing are expected to follow.

Partnered to promote local irrigation development

To further promote the development of irrigation, the design considered infill development adjacent to the canal. When the canal was originally built, irrigation was primarily developed on the west side of the canal, which is generally downslope from the canal. Since then, pumped delivery has become commonplace and has opened up large tracts of land on the east side of the canal for irrigation development. To take advantage of construction efficiencies and reduce overall costs, turnout structures were installed as part of the canal rehabilitation to service these areas at some time in the future.

Turnout M1-20 and Check Structure M1-21

4. Environmental Benefits

The multi-year program to rehabilitate the province's most important supply canal included a number of environmental aspects related to the interaction with both the natural terrestrial and aquatic environments. The impacts of this project extend far beyond the canal and are a driver of the province's Growth Plan for economic growth, expansion of the irrigated agriculture, industry, and mining, and increased agricultural production.

ENVIRONMENTAL

Interaction with the natural environment

The primary environmental achievement involved yearly construction that minimized impact to the neighbouring environment and abided by the requirements of environmental and regulatory permits. This included timing restrictions to protect migratory and nesting birds. For the rehabilitation of the inlet structure at Broderick Reservoir, which is a fish-bearing waterbody that supports recreational fishing, special attention was paid to the in-reservoir isolation works. This consisted of an earthen cofferdam and required protection against silt and sediment, which was provided by a turbidity curtain. A fish rescue was conducted as the work area was dewatered where fish were captured, catalogued, and returned to the reservoir. The condition of the cofferdam and sediment control systems were monitored daily while in place.

Responsible agricultural drainage

The project served as an example of responsible agricultural drainage and required a balance between environmental preservation and enhancing agricultural productivity. There were a number of existing drainage channels and creeks that the canal crossed. In replacing the original infrastructure, the canal crossings were sized to match the original capacity, which provides a baseline to govern future drainage improvements in the upstream catchment areas. In areas where the canal interrupted the natural drainage patterns, inlets were provided to intercept runoff flows. This followed the framework of WSA's Agricultural Water Management Strategy and presented WSA as a good neighbour by mitigating potential ponding created by the canal.

Restoration of agricultural lands

Through decades of seepage from the canal operation, neighbouring fields developed areas of salinity to a point where some locations only supported weed growth. Through lining of the canal, seepage flow has been mitigated and restoration of the affected lands can now begin.

The construction areas along both sides of the canal required the temporary use of productive farmland. For earthworks construction, the soils were stripped separately by its A and B horizons (topsoil and subsoil) and subsequently replaced in the same fashion. This helped to retain the natural segregation of the soil horizons and restore its agricultural productivity following construction.

AESTHETICS

The canal and structures were constructed in the 1960's and the next notable improvement was installation of a surface plastic liner in the 1990's. Prior to the major rehabilitation, the canal, structures, and liner had deteriorated with noticeable tears and ripples in the liner, accumulation of silt, and sloughing of canal banks. The condition of the existing surface liner was so poor that, when the wind hit the large holes from the right orientation, the liner would balloon to a height of nearly 5 m above the canal. Overall, the canal rehabilitation greatly improved the appearance of the canal by reshaping to gentler sideslopes and the placement of a granular liner, which will also reduce weed growth within the canal. Prior to rehabilitation, some structures were identified with spray-painted numbers, but all of the new structures are now identified with a professionally produced nameplate. The metal fabrications are galvanized and a consistent paint colour scheme was used for the gates and hoists at the check structures. The control buildings are precast concrete that will remain in good appearance for decades.

5. Meet Client's Needs

The design and construction services implemented by AECOM had met the needs of the WSA while exceeding the initial project objectives. As an example, the preliminary design had determined that the existing 19 bridges could be retained with some requiring just minor repairs. Compared to replacing the bridges, this presented significant cost savings and reduced the disruption to the public. At one bridge crossing, which happened to be on a primary grid road, an inspection of its buried footing during construction found that the foundation and piers were significantly deteriorated and necessitated closure. AECOM took immediate action to avoid serious injury, loss of life, and property damage. Safety was held paramount in this instance and an expedited design, material supply, and construction schedule for the bridge replacement was also implemented so that access for the public and local agricultural traffic could be restored in time for critical farming operations.

The normal operation of the canal was always maintained with no interruptions following each year of construction, which was achieved in part by continual involvement through steady, consistent, and rigorous project management. Additionally, the turnout structures required reconnection to the existing irrigation pivots so that it was available to the producer at the start of the growing season.

The project was successful in maintaining its projected budgets. Over the 10 years of the program, the design and construction contracts were delivered on time and under budget. In addition, this period included a time of significant construction activity in Saskatchewan where construction pricing and contractor availability were constantly evolving. The sum of the final contract values, including change orders, was $64.3M, which as approximately $0.8M under budget over an 11 year construction period. The total value of change orders was $1.39M or 2% of the total contract value, of which a third of this is attributed to the emergency bridge replacement described above.

Table of Yearly Construction Contracts

Year	Description	Original Contract Value	Change Order Amount	Actual Contract Value
2011	M1-4, M1-5, M1-24 Cross-Drains	$360,152.00	$0.00	$433,516.00
2011-2013	Reach 2C	$2,116,550.00	$140,862.53	$2,149,702.28
2012-2013	Reach 2A & 2B	$4,439,750.00	$0.00	$3,858,554.59
2013-2015	Reach 3A Major Structures No. 1	$4,928,128.00	$106,917.47	$4,934,629.97
2014-2016	Reach 3B & 3C	$5,759,555.00	$112,918.96	$5,486,703.08
2014-2015	Reach 4A & 4B	$3,509,375.00	$12,000.00	$3,364,099.75
2015-2016	Reach 4C	$5,423,980.00	$121,430.00	$5,293,536.13
2015-2017	Reach 5A Major Structure No. 2	$5,950,924.00	$56,290.23	$5,828,419.27
2016-2017	Reach 5B, 5C, 6A Major Structure No. 3	$8,260,670.00	$456,516.37	$8,586,814.65
2016-2017	Reach 6B.1	$2,731,347.50	$124,212.12	$2,884,150.20
2017-2019	Reach 6B.2, 6C	$4,510,650.00	$21,612.00	$4,532,262.00
2017-2018	Reach 6D Major Structure No. 4	$7,079,760.00	$136,796.20	$6,878,614.23
2019-2020	Reach 1A & 1B	$10,111,650.00	$97,763.65	$10,104,141.26
	TOTAL	$65,182,491.50	$1,387,319.53	$64,335,143.41