AECOM

Irrigation Sector – Conservation, Efficiency, and Productivity Planning Report

Prepared for:

Alberta Irrigation Sector CEP Plan Steering Committee

Prepared by:

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December 7, 2009 Project Number: 5692-005-00-4.0

Ron McMullin
Executive Director
Alberta Irrigation Projects Association
400 – 4 Avenue South
Lethbridge AB T1K 7H5

Dear Mr. McMullin:

Re: Irrigation Sector – Conservation, Efficiency and Productivity Planning Report

AECOM is pleased to provide you with one printed paper copy and two CD digital versions of the final report for the above study. This also includes a separate bound paper copy of the associated appendices, digitized on to the two CDs as well.

This has been a challenging project as the irrigation sector has led the way in the development of an innovative planning guide to give that sector direction in furthering its gains in water use conservation, efficiency and productivity. As we are confident, through our collaboration with your project steering committee, that this document will serve the sector well through the next several years as a reference for benchmarks, targets and opportunities to achieve the desired outcomes.

We have appreciated the opportunity to work with you.

Sincerely,
AECOM Canada Ltd.

for Wally Chinn, P.Eng.

WC :blb
Encl.

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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Acknowledgments

The development of this report would not be possible without the contributions of many individuals and organizations. The authors would like to recognize these contributions, without which many of the perspectives, details and analyses would not be possible.

The members of the project Steering Committee are thanked for their vigilant guidance, deliberations, document reviews and input to achieving final consensus in the development and purpose of the final report. The associated contributions from a diverse group of stakeholders, through workshop participation and reporting reviews, have been most helpful. The project coordination, on behalf of the Steering Committee, provided through the efforts of Alberta Agriculture and Rural Development staff is much appreciated.

Although the report itself has been prepared by staff from AECOM, it could not have done so without the technical support from several staff members of the Water Resources Branch of Alberta Agriculture and Rural Development and the information and data contributions provided by the Irrigation Districts through their Alberta Irrigation Projects Association. Similarly, the staff of Alberta Environment's water administration office is recognized for their work in supplying required comprehensive water licensing data.

Finally, Alberta Environment and the Canada-Alberta Water Supply and Expansion Program (CAWSEP) are both recognized, on behalf of the project Steering Committee, for supplying the necessary funding to enable the development of this report.

Executive Summary

Background

The Alberta Water Council (AWC) has a mandate to encourage Alberta water-use sectors to work toward achieving the goals of the Alberta Government's Water for Life Strategy. The irrigation sector has accepted the challenge of being one of the first sectors to develop a Conservation, Efficiency and Productivity (CEP) plan that would lead to improvements in the efficient use of water and to gains in productivity from the use of that water.

To guide the development of the irrigation sector CEP Plan, a multi-stakeholder steering committee was assembled. Members represented the interests of both irrigation districts and private irrigators, as well as the Alberta Irrigation Projects Association (AIPA), regional municipalities, watershed planning and advisory councils, environmental interests, the livestock industry, Alberta Agriculture and Rural Development (AARD) and Alberta Environment (AENV).

AECOM has been contracted by the Steering Committee to prepare this CEP Plan development report on behalf of the Committee and the irrigation sector, the intent being to derive a strategy that would guide the sector towards achieving continued identifiable CEP gains. As the Committee was unable to arrive at full agreement on all aspects of potential future direction, AECOM was directed by the Committee to provide a summary of its findings and projections and to make recommendations for further consideration by Alberta's irrigation sector.

Introduction

Irrigation in Alberta can be divided into two sub-sectors, namely:

- Irrigation districts, and
- Private irrigation

More than 81 percent of Alberta's irrigation area resides within the geographical boundaries of the 13 irrigation districts. Nearly 6,000 irrigation district agricultural producers, involving more than 548,000 hectares of land, operate exclusively within the South Saskatchewan River Basin (SSRB) and irrigate under the authorities of the *Irrigation Districts Act* and the *Water Act*.

Beyond the irrigation districts, across all major river basins in Alberta, there are another 125,700 hectares of land irrigated through privately developed, owned and operated irrigation projects. There are nearly 3,000 such schemes, ranging in size from a few hectares to a few thousand hectares, all operating under the authority of, and licensing under, the *Water Act*. Approximately 89 percent of all the area irrigated through these private projects resides within the geographical area defined by the SSRB and the Milk River Basin (MRB). Generally, outside of this region, irrigation is less intensive and more supplemental in nature.

The sum of the land base licensed for irrigation purposes through private irrigation and within the irrigation districts, situated within the SSRB and MRB, represents 98 percent of the total of all Alberta's irrigated area. Further, of the nearly 3.84 billion cubic metres of water licensed for withdrawal for irrigation purposes in Alberta, the irrigation district and private project authorizations, solely within the SSRB and MRB, account for 99 percent of that provincial total. Irrigation licensing almost exclusively refers to surface water, as groundwater supports a minimal amount of irrigation in Alberta. Therefore, because the vast majority and highest intensity of Alberta's irrigation occurs within the SSRB and the MRB, these two basins define the area of focus for this report.

On a provincial basis, less than eight percent of Alberta's average annual water outflow is allocated for use. Only half of that is actually withdrawn, and only about half of the water that is withdrawn is actually consumed, the other half being returned to the natural watercourse. However, in the SSRB and MRB combined, the situation is much different. About 59 percent of the water supply has been allocated. All of the unallocated proportion is required to meet apportionment commitments and to try to satisfy in-stream flow needs. Irrigation allocations represent 73 percent of all water allocated in the SSRB and MRB (or approximately 43 percent of the annual average natural outflow). The actual annual withdrawals through the past 32 years (1976 to 2007), have only averaged approximately 66.4 percent of the volume allocations. Nonetheless, the irrigation sector is the major diverter of water and is notably the largest net consumptive user of water, now consuming slightly in excess of 80 percent of what it diverts. The net result is that, on average through the past 32 years, irrigation's net consumption, in the SSRB and MRB combined, has been approximately 23 percent of the average annual natural outflow of these two watersheds (43% x 66.4% x 80%).

Irrigation development and its related services and productivity are recognized as contributing in a major way to socio-economic development in Alberta, particularly in the semi-arid regions of the southern portion of the province. However, irrigation is the dominant user and consumer of available water supplies and has a significant impact on the natural river aquatic systems.

The irrigation sector's water use management has improved dramatically through the last 30 to 40 years. Continuing efficiency gains will provide opportunities for the saved water to be directed to uses which can increase agricultural productivity and expand multi-purpose use, including environmental enhancements or replenishment to the natural aquatic ecosystems.

The management of irrigation water diversions and use is complex. While irrigation and associated water uses add to the collective good, many interests beyond the irrigation agriculture producer are affected by irrigation water operations. The irrigation sector is cognizant of its relationships and impacts within the watersheds in which it operates.

Goals and Objectives of the Irrigation Sector CEP Plan

In order for the CEP plan to provide a cohesive direction for all sector members, the CEP initiatives developed needed to address the sector's generally agreed-upon vision for its future and the goals toward which it would strive.

Vision: *"The irrigation industry will increase its economic contribution to Alberta through the wise and sustainable use of allocated water, to produce food, stimulate economic growth and rural development and supply water for multi-purpose use, mindful of its need to support aquatic systems restoration, wherever feasible."*

Goals:

- improving water management in all phases of irrigation operations,
- adopting superior technology and maintaining irrigation works in good condition,
- reducing or mitigating environmental impacts,
- proceeding with irrigated area growth in a prudent and cautious manner,
- increasing production of more diversified and higher-value commodities,
- increasing the availability of diverted water for multi-purpose use, and
- maintaining good quality water supplies for all users.

Not all irrigation districts are alike, just as private irrigation schemes are diverse in their scope and operational situations. As a result, the opportunity to make effective CEP gains will vary from one district to another and from one private project to another. However, because of the extensiveness, complexity and the diversity of the irrigation district water management systems, it is within the irrigation district operations that the greatest CEP gains are projected. The Alberta Irrigation Projects Association (AIPA) has taken on the role of championing the irrigation sector CEP plan and providing a focal point for the irrigation districts' collective voice.

Irrigation – Part of a Complex Water Management Operating System

There are many and different water users, besides irrigation, that place water demands on the river systems of the SSRB and MRB. The works of the irrigation delivery systems often serve as the conveyance network upon which many towns, villages, industries, livestock feeding operations and wildlife management projects rely for their water supplies. From servicing domestic water users to wetland maintenance, from food processing to sustaining sport and commercial fisheries on off-stream reservoirs, the irrigation infrastructure provides water for multi-purpose use.

So intensive is water management in the SSRB and MRB that adjusting the water delivery to one major user on one river can affect the available supply to a user on another. Balancing operations to meet the priority of water diversions, the operational demands of apportionment agreements and minimum instream flows has proven to be a challenge, but one that is met with broad-based integration and cooperation from all parties.

The Changing Nature of Irrigation in Alberta

During the last three decades, the irrigated area in Alberta has increased by nearly 50 percent, almost three-quarters of that growth occurring within the irrigation districts. However, during that same time period, the trend in longer-term irrigation district annual gross water diversion volumes from source-rivers has been declining slightly, as shown in Figure (i). These two conditions translate into a significant reduction in the amount of water being diverted "per unit area" of irrigation, a reflection of the efficiency and conservation gains being made.

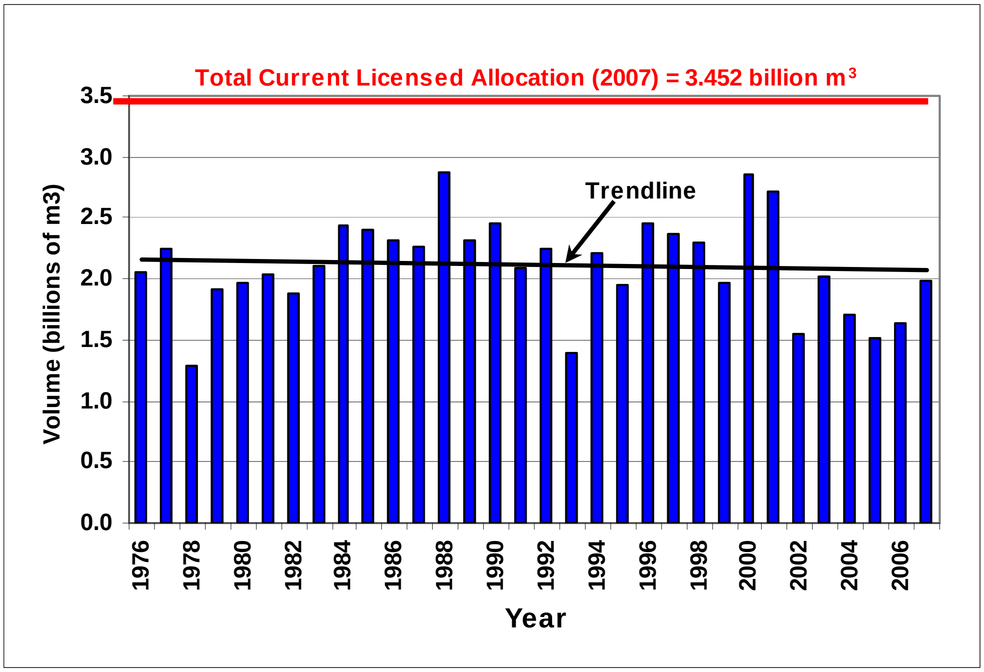

Figure (i): Annual volume of irrigation district diversion demand.

Overall irrigation water-use efficiency is defined as the ratio between the net volume of water consumed by a crop and the gross volume of water diverted from its originating source.

Much of this efficiency improvement has resulted from the shift in on-farm irrigation systems to more efficient water application methodologies. More than one billion dollars worth of technology upgrades have been acquired, paid for almost exclusively by the individual irrigation producer. From 1965, where almost 94 percent of the land base was irrigated by surface (flood) irrigation systems, to 2007, where nearly 70 percent of Alberta's irrigated area was covered by more efficient centre-pivot sprinkler systems, on-farm application efficiencies increased from less than 30 percent to more than 73 percent. As the on-farm use component involves more than 70 percent of the water diverted through to irrigation district users and almost 100 percent of that diverted to private irrigation operations, improvements in water use at the farm level return large dividends in water savings.

In addition, through the last 40 years or so, the extensive infrastructure that diverts, conveys and stores water for irrigation users has been going through an extensive process of rehabilitation and expansion. Through this process of renewal, the irrigation district infrastructure is now valued at $3.5 billion, including more than 7,600 kilometres of conveyance canals and pipelines, nearly two hundred major structures and almost 4,500 kilometres of drainage works. This has resulted in more timely and efficient water delivery, less water lost due to seepage, with near elimination of adjacent land degradation associated with seepage conditions, as well as significant reductions in return flow volumes.

Through the past four decades, ***overall*** irrigation district water-use efficiency has seen more than a four-fold increase, from an estimated 12 percent efficiency to nearly 54 percent. (These efficiency values include the assumed "loss" of the volumes of water returned to the watershed, even though these do not accumulate as a consumptive loss component.) Some continuation of that efficiency improvement is projected, but efficiency gains are beginning to taper-off as most pertinent and available technologies are already being implemented. As stated earlier, despite increasing irrigation area and more water being supplied or conveyed to other users through their works, irrigation districts are only diverting, on average each year, approximately 66.4 percent of their licensed allocation.

AENV's water management infrastructure in Alberta, valued at more than eight billion dollars, includes on and off-stream reservoirs plus 345 kilometres of inter-connecting supply canals that provide the base of support to downstream irrigation districts, private irrigators and an inter-related system of other water users. AENV's reservoir capacity, combined with that of the 40 reservoirs within the irrigation districts, provide nearly three billion cubic metres of water storage capacity, which supports a variety of irrigation, agricultural, municipal, industrial and wildlife habitat uses.

Return Flow

As a result of the infrastructure upgrades and operational and management changes that have been occurring within the irrigation sector through the past few decades, the amount of spill or return flow has been declining. However, some return flow is unavoidable. Much of the irrigation water returned is unused water that is inherently required within the operations of canal conveyance systems to sustain appropriate hydraulic operating conditions. In a limited number of situations, return flow can be beneficial when supplementing flows to a receiving watercourse that may be encountering critical supply shortages.

The on-going net overall reduction in return flow volumes from irrigation is seen as potentially one of the most significant opportunities to reduce river diversions and/or to enable expansion of irrigation area.

Irrigation Water Use Productivity

The measurement of irrigation productivity correlates water used relative to the quantity of commodity produced. A rudimentary "Irrigation Productivity Index (IPI)" has been developed. It tracks the primary production levels of specific irrigation-reliant crops (sugar beets, potatoes and soft white spring wheat) with the amount of water diverted to irrigate those crops. From 1980 to 2007, the IPI trendline has been increasing at a rate of 0.2 kilograms of produce per cubic metre of water per year. (The inherent complexities of irrigation water use and its impact on value-added production, on related tertiary economic benefits and the sector's ability to support multi-purpose use can lead to a whole other level of productivity considerations. However, for the purposes of this CEP analysis, only direct, commodity-related measures are considered.)

Understanding the Implications for Saved Water

Gains in water use efficiencies or reductions in water use ("conservation") could translate into reductions in diversions, thereby benefiting the source aquatic systems. Alternatively, saved water could be diverted to irrigation use across an expanded area or expand or enhance other uses (domestic, agricultural, environmental, etc.). The expanded use of that saved water could translate into further productivity, also a goal of improved water management.

Based on current irrigation efficiency levels, for every one percentage point in overall efficiency gain across 500,000 hectares of irrigated area, the resulting saving in water would equate to approximately 39 million cubic metres per year. To put this into context, that volume would be sufficient to supply eight new sugar refineries or potato processing plants, or to sustain 1,800 hectares of wetlands, or to double the combined minimum instream flow of the St. Mary and Belly Rivers through the four-month summer period.

To date, as allowed under provincial legislation, where irrigation districts have realized sufficient efficiency gains, some irrigation expansion has occurred, utilizing the water saved through those efficiency gains to irrigate the expansion areas. There still appears to have been an overall reduction in the volume of gross diversion, to the benefit of the rivers' aquatic environments. However, it should not be assumed that future efficiency gains will automatically translate into reduced diversions that will replenish flows in the source-rivers. The authority to divert and use the volume of water allocated within the licences is held by the licensees, provided the use is in keeping with the terms and conditions of the licences and in accordance with provincial legislation.

Irrigation Water Demand

Irrigation water demand can vary dramatically from one year to another, more than doubling from the lowest-demand year to the highest. The demand for irrigation water is intrinsically linked with precipitation and temperature conditions (and to a lesser extent the mix of crops grown). During the past 32 years, average growing season agro-climatic conditions have remained basically unchanged, while diversion amounts per unit of irrigated area have decreased by an average of 1.2 percent per year.

In developing projections for water demand, statistical trends and state-of-the-art computer modelling have been employed. AARD's Irrigation Demand Model (IDM), integrated with a very comprehensive database, cooperatively developed with the irrigation districts, has been a valuable resource in deriving longer-term scenarios and projected outcomes.

Efficiency gains are projected to continue through the next 10 to 15 years. The greatest gains will be accrued from on-going improvements at the farm-use side, where a greater percentage of the delivered water will get to the crop, and in the rehabilitation of irrigation water distribution works, where the greatest effect will be realized through reduced return flows.

Based on derived projections of reasonable potentials for future efficiency improvements, the following tabular summary lists the reductions in Gross Irrigation Diversion Demand (GIDD) projected to be achievable by the irrigation sector in the next 10 to 15 years; in particular through gains made by the irrigation districts.

Table (i): Potential Reductions in Gross Irrigation Diversion Demand (GIDD)

Irrigation Component	Net GIDD Reduction	Water Saved*
On-Farm Use	4.2%	18 mm
Conveyance/Distribution	1.0%	4 mm
Reservoir Storage	0.0%	0 mm
Return Flow	9.8%	43 mm
Total	**15.0%**	**65 mm**

** Water saved is expressed in equivalent depth per unit of irrigated area.*

There are, of course, unknowns that can affect the real ability to achieve these results. One of the major uncertainties is the effects arising from projected climate change that is associated with global warming. Although work in this area, particularly with respect to potential impacts on Alberta irrigation, is quite limited, AARD's computer modelling has derived some projections for consideration. With projected reductions in growing season precipitation, coupled with projected higher temperatures that yield increased evapotranspiration, the net result could mean an average net increase in annual gross diversion water requirement of approximately four to five percent. Therefore, some of the projected water-savings accrued through efficiency gains, may have to be directed back into supplying the existing irrigation area to compensate for the projected global warming effect on irrigation demand.

Water Supply for Irrigation

Additional water storage capacity, where it can be effectively developed and operated, is seen as a potential benefit to all water users. This is particularly true with regard to on-stream storage, although this concept does generate concern within the environmental and some other constituencies. However, the aspect of developing on-stream storage is beyond the scope of an irrigation sector plan and so is set aside in this discussion.

A major longer-term uncertainty for the irrigation sector is the potential effect of global warming-induced climate change on the availability of water. Currently, directly relevant analyses of these climate change water supply prospects is even more limited than projections for irrigation water demand. Nonetheless, based on the most recent analyses carried-out, it is projected that, within the SSRB, annual flow volumes could see a reduction of approximately eight percent. An additional significant factor in managing the water supply under climate change scenarios concerns the potential for extreme variability in basin flow regimes which may significantly impact the ability to capture, divert and store the available water.

Identifying CEP Opportunities

Through the development of this CEP planning document and projections for increasing water-use efficiencies, general water-use guiding principles and outcomes for the irrigation sector have been derived and are summarized as proposing:

- That annual gross diversion will not increase, on a total volumetric basis, from historical diversions.
- That annual gross irrigation diversions will continue to decrease, on a per unit of irrigated area basis, from historical diversions.

A broad-based multi-stakeholder workshop was convened in September, 2008, to discuss and develop opportunities and initiatives upon which the irrigation sector should focus to achieve desired CEP gains. An extensive list of suggestions and recommendations was compiled and ranked by each individual participant to indicate their preference for proposed initiatives that they felt had the greatest potential to achieve the desirable CEP gains.

Establishing CEP Targets

Upon analyses of past efficiency accomplishments, the current state of the sector and the projections for future improvements and related water supply and demand, a derivation of selected CEP targets to achieve in the next 10 to 15 years was undertaken. In establishing targets, agreed-upon benchmarks for the current state of water use also needed to be derived.

In reviewing historic data, the two major variables that influence benchmark-setting are:

- The significant variability in irrigation water demand, that has been demonstrated to occur from one year to the next, as influenced by variable agro-climatic conditions, and
- The historical growth in irrigated area relative to overall gross diversion amounts.

In order to neutralize the effect of those variables, as much as possible, area-weighted diversion volumes were derived and these adjusted volumes were blended together to derive a series of 10-year rolling-average diversion volumes. The results, as presented in Figure (ii), indicate the historic decline in diversion volumes, relative to area irrigated, and also provide benchmark reference points. Consensus was reached, and (as supported within the *"Water for Life"* strategy) the year 2005 was selected to be the bench mark year.

Similar analyses were carried-out to examine the longer term integrated effects of on-going efficiency improvements on diversion requirements, as may be affected by projected cycles of higher and lower water demands. The demand analyses were further compounded by imposing some year-to-year irrigation area expansion. From the analyses of applying projected CEP opportunities, the following targets are recommended for adoption by the irrigation sector.

1) That the annual gross irrigation diversions, totalled for all irrigation districts and calculated as 10-year rolling-average volumes, not exceed 2.186 billion cubic metres. (It is recognized that, in any given year, due to weather and / or to crop conditions, the actual diversion may exceed this level, but will not cause the ten-year rolling average limit to be exceeded.)

2) That, within the next 10 to 15 years, the annual gross irrigation diversions, averaged for all irrigation districts and calculated as 10-year rolling-average depths per unit of irrigated area, will continue to decrease from 441 millimetres to a target level of approximately 385 millimetres. A comparable target for private irrigation projects is recommended to be 320 millimetres, **on average.**

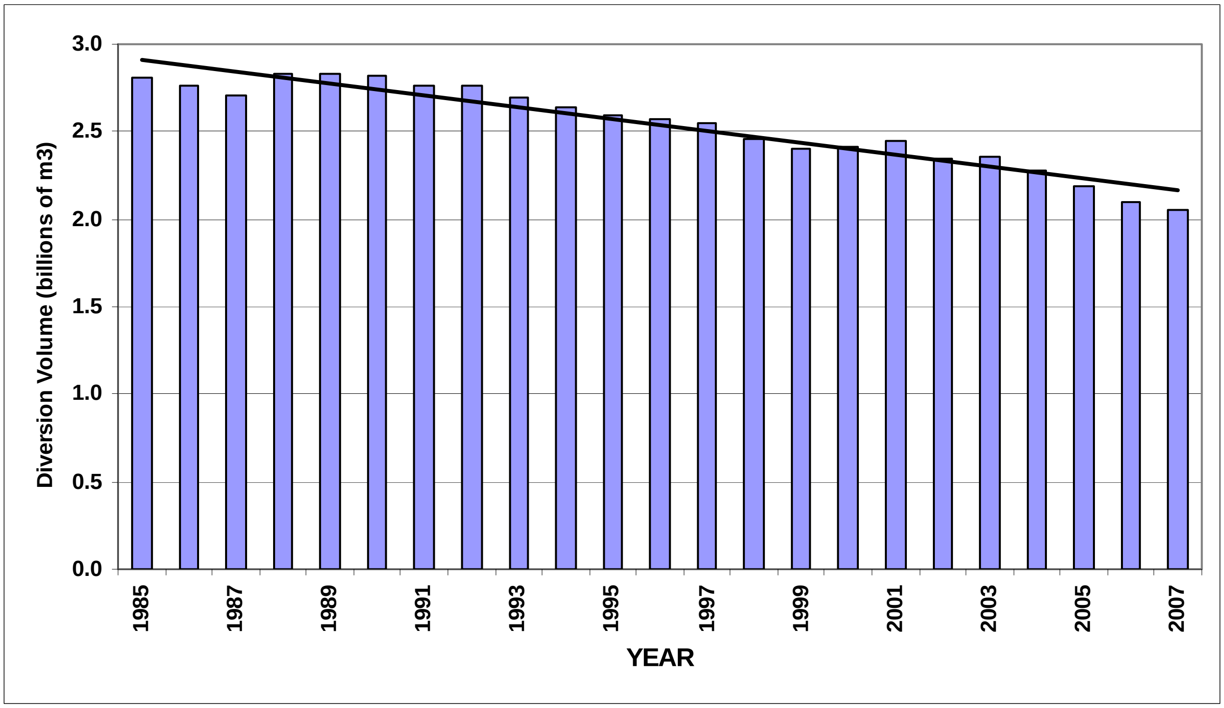

Figure (ii): "Area-adjusted" 10-year rolling-average diversions with trendline.

3) That, within the next 10 to 15 years, the total amount of return flow, averaged for all irrigation districts, be reduced to half of the 2005 rolling-average amount of 86 millimetres, to a level of 43 millimetres per unit of irrigated area.

4) That, within the next 10 to 15 years, the average level of overall irrigation efficiency within the irrigation districts is increased from the current level of nearly 54 percent (year 2005) to almost 63 percent. This nine-percentage point gain equates to approximately a 17-percent improvement from the base reference year (2005) efficiency level.

5) That, by 2015, the currently measured long-term average productivity trendline, expressed as units of commodity produced per unit of water diverted for the irrigation of sugar beets, potatoes and soft white spring wheat, increase from 8.8 kilograms per cubic metre (year 2005) to at least 10 kilograms per cubic metre. This increase would equate to approximately a 14-percent improvement from the base reference year (2005) productivity measurement.

The following is an abbreviated summary of general recommendations which are provided in more detail at the conclusion of the main report. They have been developed in addition to the foregoing targets to help guide the irrigation sector in adopting and implementing this CEP plan. In order for the irrigation sector to better implement this CEP plan and achieve the recommended targets, it is recommended that:

1) The Alberta Irrigation Projects Association provide guidance and encouragement to the Alberta irrigation district community, to enable each of the 13 districts to develop its own Water CEP strategy that is complementary to this Sector planning document.

2) The irrigation districts, through the AIPA and with the assistance of AARD, develop a strategic plan for the on-going evaluation of progress toward achieving CEP gains.

3) The irrigation districts and private irrigators embark on a process to develop a much broader approach to measuring productivity gains.

4) The AIPA establish a formalized process of providing awareness and education with respect to the implementation of this plan.

5) The private irrigation communities develop or formalize representative organizations, so as to be able to address related water uses on a broader scale to other stakeholders and government agencies.

6) Irrigation districts, the AIPA and private irrigators enter into cooperative agreements with technical partners to enable the development and execution of specific CEP research and development projects.

7) Irrigation districts expand and enhance the recording and reporting of their water operations data to better distinguish between flows directed specifically to irrigation purposes and those quantities delivered for other uses.

8) Irrigation districts expand and enhance, where necessary and advantageous, the rigorous and consistent monitoring and reporting of return flows from their operations.

9) Irrigation districts that have not already done so, implement a comprehensive policy and field program of restricted limits on water deliveries to irrigators that will encourage water conservation on the part of end-users.

10) Private irrigators and AENV, in cooperation with other water management and research and development agencies, derive water measurement and tracking systems that can be incorporated into private irrigation projects to better monitor and quantify water use by private irrigation operations.

11) The irrigation district community investigates collaborative opportunities to acquire additional funding for the rehabilitation of irrigation infrastructure, targeting this additional funding to support projects which emphasize the re-development of works where efficiency and potential productivity gains can be optimized and demonstrated.

12) Consideration is given, by appropriate provincial and federal jurisdictions as well as by irrigation districts, to implement incentive programs, which will enable irrigation producers to up-grade their on-farm systems to higher-efficiency technologies.

13) Where efficiency gains can be demonstrated, that irrigation districts and private irrigators give consideration to utilizing water marketing opportunities for the apportioning of licence allocations to benefit economic growth in other sectors and/or for the enhancement of aquatic environment conditions or wildlife habitat.

14) While irrigation area expansion is seen as one of several options for the potential productive use of saved water, such expansion should be approached with due care and attention to the unpredictability of future climate situations and the projections for potentially warmer and drier conditions.

15) Irrigation water conveyance agencies such as AENV and irrigation districts develop their water conveyance systems to minimize, as much as possible, the entrance of surface water run-off into these systems.

16) The irrigation sector collaborate with water resource management agencies in Alberta, to determine opportunities to optimize diversions into storage during high flow periods, thereby reducing the need for large diversions during natural low-flow periods.

17) The irrigation sector schedule a formalized review of its CEP plan, on a five-year cycle, in order to document progress toward CEP goals and to make adjustments in benchmarks and targets as necessary and appropriate.

18) The irrigation sector continues the dialogue with other stakeholders to develop mutually-acceptable and beneficial opportunities for increased water use conservation, efficiency and productivity.

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1. Irrigation Sector CEP Plan Overview

1.1 Introduction

The Alberta Government's *Water for Life* Strategy has set a target for Albertans to achieve a 30 per cent improvement in water-use efficiency and productivity. The Alberta Water Council (AWC) was established by the Province to spearhead this goal.

Under the auspices of the AWC, a Conservation Efficiency Productivity (CEP) Team recommended that seven major water-using sectors in the province prepare a CEP plan to guide their sector towards achieving the *Water for Life* goal. The CEP team prepared a set of guidelines in the form of an "Annotated Table of Contents" for the development of the plan, a framework to guide the process, and a set of criteria by which the plan would be evaluated. The irrigation sector volunteered to be one of the first sectors to prepare a CEP Plan and pilot the use of the Annotated Table of Contents. This plan development report follows the guidance of the Annotated Table of Contents, adhering to the intent and providing the required content as much as currently possible.

An Irrigation Sector CEP Plan Steering Committee[1] was struck to oversee the development of this plan. Since there are many and diverse interests in irrigation water use, the committee included representation from the irrigation districts, the Alberta Irrigation Projects Association (AIPA), private irrigators, Watershed Planning and Advisory Councils, municipalities, environmental interests, the livestock industry, Alberta Agriculture and Rural Development (AARD) - Water Resources Branch, and Alberta Environment - Water Management Operations Division. First Nations were also invited to participate, but to date have not been involved in the committee's deliberations.

The Irrigation Sector CEP plan is to report on the current state of irrigation water use in Alberta, on progress that has and is being made toward more efficient use of the resource, and on identifying potential mechanisms to enhance CEP efforts. The report is also to recommend specific measures the sector should focus on to achieve further CEP gains and to define targets and mechanisms that will assist the irrigation sector in achieving the CEP gains targeted through AWC's response to Alberta's *"Water for Life"* Strategy (2003).

AECOM has been contracted by the Steering Committee to prepare this CEP Plan development report on behalf of the Committee and the irrigation sector, to derive a strategy that would commit the sector to identifiable on-going CEP gains. Since the Steering Committee was unable to achieve complete agreement on all items, the Committee directed AECOM to provide a report that would delineate its findings and projections, providing recommendations to Alberta's irrigation sector to help it move forward and continue making CEP gains.

[1] The Irrigation Sector CEP Plan Steering Committee is detailed in Appendix A of this report.

1.1.1 Definitions of Terminology

According to the 2007 report[2] issued by the AWC, the following are the accepted definitions of Conservation, Efficiency and Productivity (CEP) for plan development:

Water Conservation:

- Any beneficial reduction in water use, loss or waste.
- Water management practices that improve the use of water resources to benefit people or the environment.

Water use efficiency:

- Accomplishment of a function, task, process or result with the minimal amount of water feasible.
- An indicator of the relationship between the amount of water needed for a particular purpose and the quantity of water used or diverted.

Water productivity:

- The amount of water that is required to produce a unit of any good, service or societal value.

The Irrigation Sector CEP plan relates its goals, objectives and actions to the foregoing definitions.

1.1.2 Irrigation Sector Overview

For this report, the term "irrigation sector" refers to all commercial operations specifically related to the field production of agricultural commodities and which are authorized to use water under Alberta's *Water Act* for "irrigation purposes". It does not include other irrigation operations such as golf-course or park watering.

Irrigation occurs in some form across most of Alberta's agricultural regions and totals approximately 675,000 hectares. This constitutes about two-thirds of the irrigated area in Canada. Alberta's irrigation sector can be divided into two sub-sectors:

- Irrigation districts, and
- Private irrigation.

The majority of the irrigation occurs within the geographical boundaries of 13 irrigation districts, all of which are located in the southern region of the province and more specifically within the South Saskatchewan River Basin (SSRB). They operate under the authority of the Province of Alberta's *Irrigation Districts Act* and are granted rights to withdraw water under the terms of various licences issued through the provisions of the province's *Water Act*. The Irrigation Districts' infrastructure is comprised of a sophisticated network of reservoirs, canals and pipelines that supply water to nearly 6,000 agriculture producers, irrigating more than 548,000 hectares of land (AARD[3] 2008), and encompassing about 81 percent of Alberta's total irrigated area.

[2] *"Water Conservation, Efficiency and Productivity: Principles, Definitions, Performance measures and Environmental Indicators".*

[3] *AARD refers to Alberta Agriculture and Rural Development. For simplicity, this acronym will be used to reference any documentation sources also attributable to Alberta Agriculture, Food and Rural Development (AAFRD) or Alberta Agriculture and Food (AAF) which are all one in the same.*

Private irrigation entails a multitude of irrigation projects that have been developed and operated by individual producers or enterprises, each with their own works and licences to divert and supply water authorized through the *Water Act*. Although, they are primarily located within southern Alberta, private irrigation projects can be found throughout much of Alberta's agriculture zone. Projects range in size anywhere from a few hectares to a few thousand hectares, with a total irrigated area across Alberta of 125,750 hectares. There are nearly 3,000 of these independently-operated projects.

Within the SSRB and Milk River basin, there are approximately 112,000 hectares of privately-irrigated land, or 89 percent of the province's private irrigation. When added to the irrigation district area, the total of 660,880 hectares represents 98 percent of Alberta's irrigated area. In the more northerly areas of Alberta, precipitation is more plentiful and irrigation serves a more supplemental role than it does in the south of the province. Figure 1 illustrates the distribution of irrigated areas across Alberta.

Figure 1: The geographic distribution of irrigated areas across Alberta (AARD 2008)

1.2 Defining a Direction for the Irrigation Sector CEP Plan

According to Alberta's strategy for water sustainability, as delineated in the "Water for Life" document (AENV[4] 2003), the following principles, goals and outcomes should be the focus for any water management plan:

Principle: *Albertans must become leaders at using water more effectively and efficiently, and will use and reuse water wisely and responsibly.*

Goals:
1) *Safe, secure drinking water supply;*
2) *Healthy aquatic ecosystems, and*
3) *Reliable, quality water supplies for a sustainable economy*.

Outcomes:
1) *All sectors are demonstrating best management practices and improving efficiency and productivity associated with water use.*
2) *Water is managed and allocated to support sustainable economic development and the strategic priorities of the province.*

It is recommended that Alberta's irrigation sector develop and implement this plan as per the foregoing principle, goals and outcomes. Further, the sector should focus on striving to realize the associated long-term outcome, namely:

"The overall efficiency and productivity of water use in Alberta has improved by 30 percent from 2005 levels by 2015."

The irrigation sector in Alberta has made significant gains in its water use efficiency through the past three to four decades. While there is opportunity for further improvement in its water use efficiency, reaching a performance or outcome measure of a 30 percent improvement will be challenging to achieve, likely being achieved through a combination of productivity and efficiency gains. It is understood that the term *improvement* means that efficiency and/or productivity levels derived for 2005 conditions are expected to increase by a factor of 1.3 by 2015.

1.2.1 Goals and Objectives of the Irrigation Sector CEP Plan

The management of irrigation water diversions and use is complex. Many interests beyond the irrigated agricultural producer are affected by these water operations. While irrigation and associated uses of the water add to the collective good, the irrigation sector is cognizant of its relationship within the watersheds in which it operates. The irrigation community seeks to find that appropriate balance between maintaining an environmental ethic while enhancing its economic contributions to the province.

[4] *AENV is the acronym representing the Alberta Government's Department of the Environment.*

The following summarizes the goals or objectives that are recommended that the irrigation sector pursue, through the development and implementation of this CEP plan:

1) Continue to reduce the volume of water diverted from Alberta's rivers, lakes and streams per unit of irrigated area.
2) Increase irrigation water use efficiency and productivity by 30 percent.
3) Continue to enhance the growth of economic output per unit volume of water diverted.
4) Implement mechanisms that promote greater accountability in the use of irrigation water.
5) Increase the quantity and quality of environmental enhancement and mitigation schemes.
6) Expand opportunities for multi-purpose use of irrigation works and water.
7) Ensure that water diverted for irrigation retains an acceptable quality throughout its storage, conveyance, application and, where applicable, return to the natural watershed.

1.2.2 The Irrigation Sector Vision of its Future Water Use

Irrigation in Alberta continues to be an economic development engine. Irrigation generates at least three times the economic output as compared with dryland production on an equivalent land base (AARD 2001). Irrigation, operating on only approximately 5 percent of Alberta's cropland, produces nearly 19 percent of Alberta's agri-food GDP (AARD 2001). The high productivity, and the diversity and reliability of that productivity, together with assured water supplies for domestic, industrial, and recreational use, fostered much of the development in southern Alberta.

Southern Alberta has a semi-arid climate and the society of the region is strongly dependent on access to natural runoff sources that are quite variable. Extensive irrigation water supply works have been built over time to convey water for numerous uses, including irrigation, municipal, other agricultural uses, industry, recreation and fish and wildlife habitat. More than 33,000 hectares of wetlands exist in arid regions of southern Alberta, through the use of irrigation water, helping to mitigate the earlier losses of natural sloughs and marshes as settlement took place during the past century. It is also acknowledged that, as a result of major river diversions, the aquatic environment of the source streams has, at times, been stressed, particularly in dry years. However, many sport and commercial fisheries have also been realized through the presence of irrigation works, off-setting in part, the fishery impacts within some stressed rivers. At the same time, water captured within on-stream reservoirs sometimes is a source to augment river flows downstream of these storage facilities in order to improve the aquatic environment during natural, drought-induced low flow periods.

The following is recommended to represent the VISION of Alberta's irrigation sector.

"The irrigation industry will increase its economic contribution to Alberta through the wise and sustainable use of allocated water, to produce food, stimulate economic growth and rural development and supply water for multi-purpose use, mindful of its need to support aquatic systems restoration, wherever feasible."

To achieve this VISION, the irrigation sector will strive to meet its targets for water conservation, efficiency and productivity by:

- improving water management in all phases of irrigation operations,
- adopting superior technology and maintaining irrigation works in good condition,
- reducing or mitigating environmental impacts,
- proceeding with irrigated area growth in a prudent and cautious manner,
- increasing production of more diversified and higher-value commodities,
- increasing the availability of diverted water for multi-purpose use, and
- maintaining good quality water supplies for all users.

1.2.3 The Scope of the Irrigation Sector CEP Plan

Irrigation districts collectively are licensed to withdraw approximately 3.45 billion cubic metres of water from the Bow and Oldman River basins to supply water to some 548,865 hectares of land. Diversions within the South Saskatchewan and Milk River basins have wide-ranging impacts. Both the SSRB and the Milk River Basin are subject to apportionment agreements with neighbouring jurisdictions, resulting in water management complexities to follow specific apportionment requirements. For example, diversion operations in the Oldman River basin can have ramifications on how water diversions need to be managed in the Bow River basin, in order that Alberta's apportionment commitment to Saskatchewan is achieved. Currently, a high proportion of the flow through the Red Deer River passes unused into Saskatchewan (AENV 2002) and therefore also contributes to apportionment commitments.

All irrigation districts are not identical. They vary widely in size, topography, soil type, crop water needs, and organizational resources. As a result, there is not a "one size fits all" plan for each district. Irrigation districts can be very effective in monitoring and auditing their respective diversions and uses of water, which makes identifying efficiency gains in their operations and the reporting of progress towards achieving targets quite feasible. Individual producers in districts independently manage their on-farm water applications and irrigation equipment. As energy costs may dictate, it is in their best interest to increase water application efficiencies, which can also support higher crop productivity. Efficiency improvements also help to reduce the risk of overall water shortages that have a far-reaching effect. As technology advances and becomes more accessible, and as finances become available, irrigators will move toward more efficient systems and higher crop productivity.

The almost 3,000 private irrigation projects are located primarily in southern Alberta. Almost all of these projects divert their water supplies directly from river or lake sources and convey it through closed systems to in-field sprinkler irrigation systems. The private irrigation projects often benefit, as do the irrigation districts, from provincial water management infrastructure that regulate river flows. The operational losses of water through private irrigation schemes are generally confined to the on-farm irrigation application component, with little or no storage, conveyance or return flow losses. Private irrigators can also achieve efficiency and productivity gains, by using more efficient systems. However, due to the lack of large and lengthy open conveyance systems and return flows, efficiency gains for private irrigation will not be as pronounced as it will be for the irrigation districts.

As well, the independent nature of the private irrigation operations do not provide a structure that enables the same comprehensive water use monitoring that occurs within the irrigation districts. As a result, CEP recommendations, implementation and monitoring for this group will, by necessity, be a separate consideration apart from the irrigation districts.

Although the focus of this CEP plan is to encompass all Alberta agricultural irrigation, the 98 percent of the provincial total that is resident within southern Alberta will be the primary focus of the Irrigation Sector CEP Plan. This includes all of the irrigated area located within the irrigation districts and within the vast majority of privately-irrigated areas in the province.

1.2.4 Benefits of an Irrigation Sector CEP Plan

This plan is being developed to provide information and direction to the various constituents within the irrigation sector. The CEP Plan will identify specific and quantifiable goals or targets for improving water use and achieving measurable outcomes. In addition, this plan is intended to also provide the sector with an array of tools and mechanisms that will enable implementation and monitoring of CEP-related activities.

On the broader scale, it is intended that CEP improvements will result in additional water being available for a variety of uses, including the potential to irrigate an expanding irrigation land base. At the producer level, CEP improvements can foster reduced input costs and greater commodity returns.

Despite the substantial CEP gains that have been achieved over the past 30-40 years, there is a large segment of the public that expects the sector to make reasonable efforts to achieve the AWC's desired outcomes. The irrigation sector holds, by far, the largest amount of allocated water in the region. With the closure of the Bow and Oldman River basins to further water licensing, the availability of water for future economic development and environmental impact mitigation rests, in large part, with the irrigation license holders. A growing public expectation is that the irrigation districts should free-up water for other worthwhile uses.

Since irrigation development in southern Alberta has such broad impacts on the region, many other stakeholders such as municipalities, industrial users, other agricultural interests such as the extensive beef industry, as well as recreational and environmental interests can benefit from CEP gains. Due to the significant water quantity that the irrigation sector has received licensed authorization for diversion, any river basin watershed operations and planning initiatives must have the committed and integrated involvement of the irrigation community in order to achieve any reasonable level of public consensus and have an implementable and practical plan. Irrigation's economic, social and environmental effects have far-reaching impacts. As such, an incremental CEP gain within the irrigation component can pay significant dividends.

1.2.5 Championing the Irrigation Sector CEP Plan

The most significant gains to be realized through CEP initiatives will occur within the 13 irrigation districts. Each district is unique in its impacts and capabilities and each will make greater or lesser contributions to the projected outcomes as a result. The irrigation districts' collective efforts can be promoted by their umbrella organization, the Alberta Irrigation Projects Association (AIPA), which has a mandate to represent Alberta's Irrigation Districts' participation in education and outreach, policy development and research activities.

Much has been achieved in recent decades in irrigation sector CEP gains, primarily through collaborative initiatives between the irrigation districts, the federal and provincial governments and various other groups. To achieve further gains, for the benefit of all Albertans, these collaborations will need to continue.

2. Profile of Existing Water Systems

As indicated in Chapter 1, 98 percent of Alberta's irrigated area is located in the southern portion of the province, primarily within the SSRB, and the Milk River Basin (MRB). Therefore, irrigation operations in this region are the primary focus of the following discussion and information.

Table 2-1 provides a summary of the licensed volume of water for irrigation across Alberta as of 2008. Irrigation district allocations represent almost 90 percent of the authorized irrigation diversions. These are supported from flows arising within either the Bow or the Oldman River basins. Of the remaining 10 percent of the water licensed for irrigation purposes, 9.2 percent has been allocated to private irrigation within the SSRB and MRB watersheds, while private irrigation scattered across the rest of the province amounts to less than one percent of overall provincial irrigation allocations.

Table 2-1: Distribution of Licensed Surface Water Allocations for Irrigation in Alberta

	District Irrigation		Private Irrigation		District & Private Irrigation	
River Basin	Volume (m^3)	Portion of Total	Volume (m^3)	Portion of Total	Volume (m^3)	Portion of Total
Milk	**0**	**0.00%**	**29,867,458**	**0.78%**	**29,867,458**	**0.78%**
Oldman	1,761,056,923	45.89%	171,648,671	4.47%	1,932,705,594	50.37%
Bow	1,690,425,176	44.05%	29,800,339	0.78%	1,720,225,515	44.83%
Red Deer	0		48,422,650	1.26%	48,422,650	1.26%
South Sask.	0		72,515,884	1.89%	72,515,884	1.89%
SSRB	**3,451,482,099**	**89.95%**	**322,387,544**	**8.40%**	**3,773,869,643**	**98.35%**
All Other Basins	**0**	**0.00%**	**33,574,338**	**0.87%**	**33,574,338**	**0.87%**
Provincial TOTAL	**3,451,482,099**	**89.95%**	**385,829,340**	**10.05%**	**3,837,311,439**	**100.00%**

Data Source: AENV - 2008

It is acknowledged that there is a very small component of Alberta's irrigation that extracts its water from groundwater sources. AENV reports a total of less than 200 hectares of irrigation utilizing groundwater as a diversion source, with projects ranging from only two to 35 hectares in size. These projects typically are associated with small market garden or nursery operations. Due to their relatively negligible presence in the overall Alberta irrigation scheme, they are not considered further in this report.

Figure 2 depicts the location of the SSRB and MRB in the southern region of the province. It delineates the boundaries of the major river basins and of the 13 irrigation districts. This area is the focus of this report.

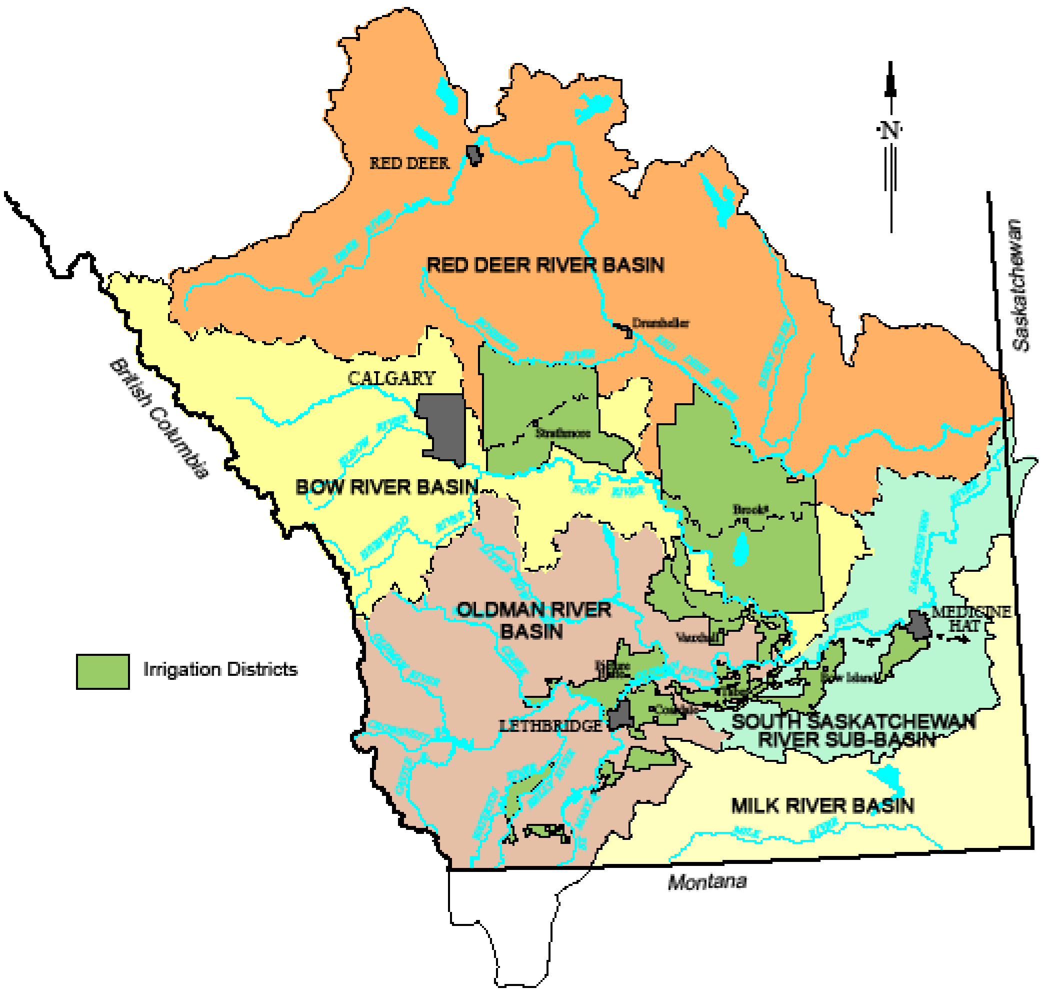

Figure 2: The South Saskatchewan and Milk River Basins account for 99% of irrigation water use

2.1 Understanding Water Management Terminology

To ensure readers have a common understanding of the terminology used in this report, this section will attempt to define some of the key terms.

2.1.1 Water Supply and Water Availability

The term *water supply* in this report will refer to the natural (or non-regulated) flow of surface water. *Available water* is that portion of the water supply that is available to be diverted for various purposes.

Runoff from major snowmelt and/or rainfall events can be so large and occur so rapidly that there is insufficient capability or capacity within the water control works to retain or divert the extremely large volumes of water. In other instances, some of the water may be unavailable due to the imposition of legislated or regulatory requirements, such as apportionment agreements with jurisdictions outside of Alberta or commitments such as maintaining instream flows.

2.1.2 Water Allocation and Water Use

Table 2-1 presents the summary of water volumes that have been authorized for annual irrigation withdrawals. These amounts represent the total licensed *water allocation* for the irrigation sector. *Water allocation* is the maximum volume of water that can be withdrawn annually from the *water supply* for the use(s) specified within the water user's licence. These allocations are approved and administered by AENV pursuant to the Alberta *Water Act*. In all cases, the actual water used (*water use*) must be equal to or less than the licensed allocation, unless AENV approves otherwise.

Figure 3 provides a breakdown of the allocated water by purpose of use across Alberta.

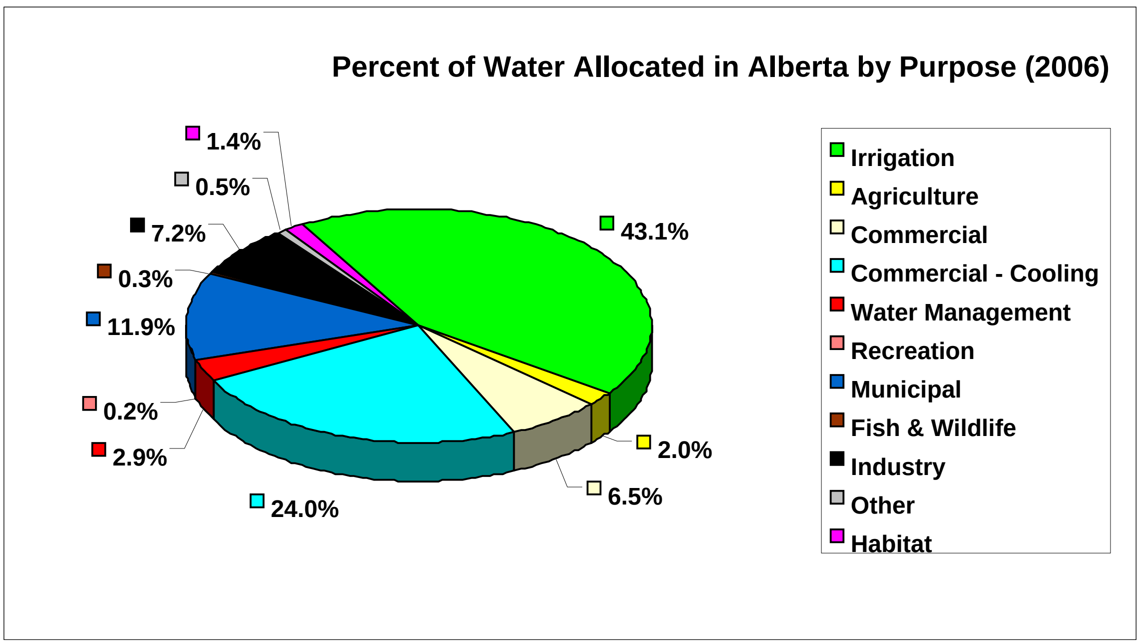

Figure 3: Distribution of Alberta's licensed water allocations by purpose (Source: AENV State of the Environment)

Irrigation use retains the largest volume, nearly double the next largest allocation, the use of water for commercial cooling. This figure does not reflect the current situation in Alberta where more than 92 percent of the total average annual water supply generated across all its watersheds remains unallocated.

2.1.3 Water Consumed and Water Returned

Not all of a licensee's water allocation is withdrawn every year. Irrigation district *water allocations* have been established in recognition of both the semi-arid climate in southern Alberta, and the districts' potential growth in irrigated area. Therefore, the actual use of allocated water is usually less than the amount *allocated*. In addition, the water that is diverted is not totally *consumed* or removed from the watershed surface water. Some *uses*, such as municipal diversions often return much of the amount withdrawn back to the source from which it was diverted. Irrigation *use* also results in water being returned to the rivers (*return flow*), but usually a considerable distance downstream from where original diversions took place. Nonetheless, because irrigation water must meet evapotranspiration demands of crops and has some distribution and application losses, it is the largest *consumptive* use of water in the province.

Figure 4 illustrates the growth in area under irrigation that has occurred in Alberta since 1976. It also illustrates the area within the irrigation districts assessed to be irrigated and the extent of area actually receiving water in those years. This varies year-to-year primarily due to differences in precipitation amounts across the region. For example, as depicted in Figure 4, 1993 and 1995 were wet years and some lands were deemed not to require irrigation applications that year.

The average annual gross water diversion, totalled for all irrigation districts is approximately two-thirds of the total licensed allocations issued to the 13 districts.

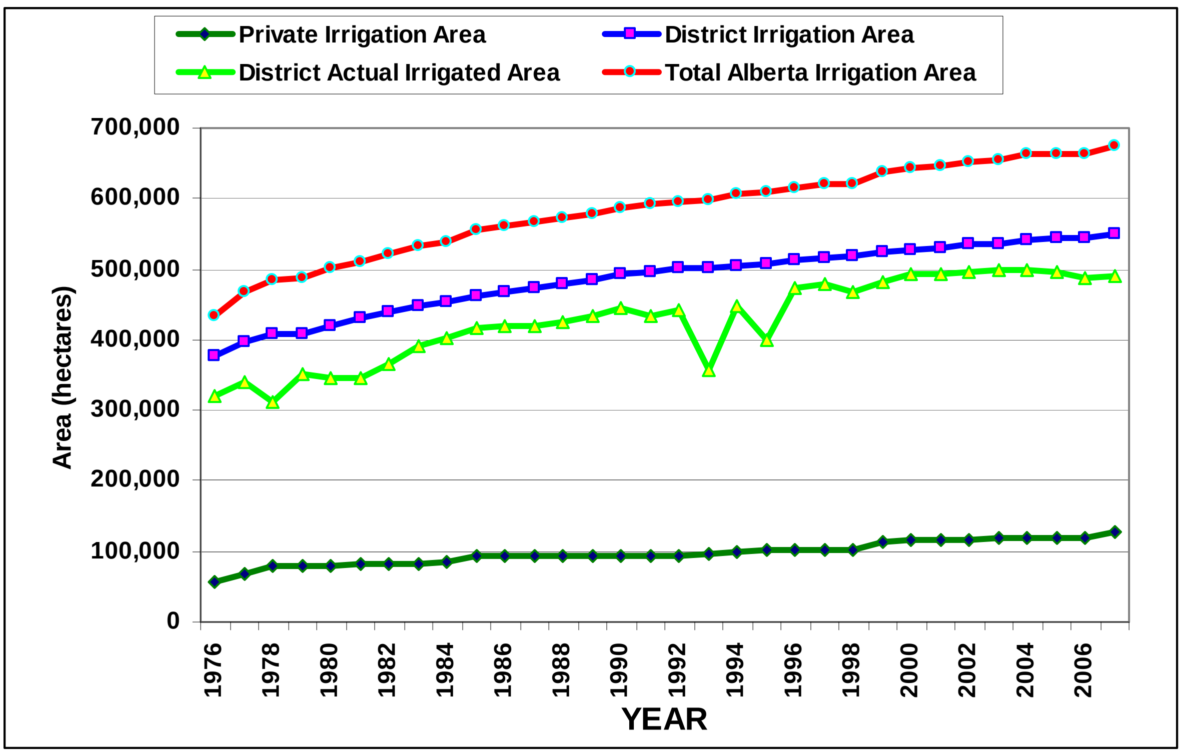

Figure 4: Growth of area under irrigation in Alberta – district and private, from 1976 to 2007 (Source AARD Annual Irrigation Information and AENV State of the Environment)

2.2 Irrigation-Supported Infrastructure and Water Use Authority

There are two major categories of water management infrastructure that are critical to the success of irrigation water management operations. These are either irrigation district owned works or provincially-owned works. The operations and linkages between the two are strongly integrated and mutually dependent in many cases.

These works include on-stream and off-stream dams, reservoirs and diversion facilities, canals, pipelines and drainage networks. Water flow within the works, with a few exceptions, is driven by gravity, with water flow primarily from west to east. In total, there is capacity to store almost three billion cubic metres (2.44 M acre-feet) of water.

2.2.1 Alberta Environment Water Management Headworks

The facilities owned and operated by AENV's Water Management Operations Division include both on and off-stream reservoirs. The water control infrastructure owned by the Province is operated for multi-purpose use and is not dedicated to irrigation, although the major use in southern Alberta is irrigation. AENV operates four major on-stream reservoirs in the SSRB. The province releases water from storage into main canals and/or into the downstream river to meet the demands of water users, the aquatic environment and, inter-provincial commitments to Saskatchewan. Three of the major on-stream reservoirs (St. Mary, Waterton, Oldman) are located in the Oldman River Basin with the stored water supporting a large irrigation demand. The fourth, the Dickson Dam, is located on the Red Deer River, and has less irrigation demand than do the Oldman storages. Two river diversion pump stations along the Red Deer River, Sheerness and Deadfish, depend on adequate Red Deer River flows to divert water to several thousands of hectares of private irrigation, as well as to other users in the Special Areas, located in east-central Alberta. The Deadfish pumped diversion is owned and operated by AENV. The Sheerness diversion is owned by ATCO power, which is reimbursed for supplying water for irrigation. AENV also operates several large off-stream storages that rely on canal inflow for the majority of their storage.

Figure 5 provides an overview of the extent of water management facilities throughout the SSRB, owned by the Province and operated by AENV. In addition to river diversion and storage facilities, AENV also manages 345 kilometres of inter-linking main canals that convey water to downstream users, including irrigation districts. The estimated total capital value of the AENV water management infrastructure across the Province is approximately eight billion dollars, with the large majority of that resident in the SSRB.

2.2.2 Alberta Irrigation District Infrastructure

The water management system within the operational responsibilities of the 13 irrigation districts is extensive and intensive. Through a collaborative venture between all the districts and AARD, an Irrigation District Infrastructure Management System (IDIMS) has been developed (AARD 2002) and is updated annually. This inventory of works quantifies the amount of irrigation district works that are owned and operated by these organizations and also provides a detailed measure as to the physical and operating condition of these works. Table 2-2 summarizes the extent and estimated current capital replacement value of these works, as of 2007 (AARD 2008).

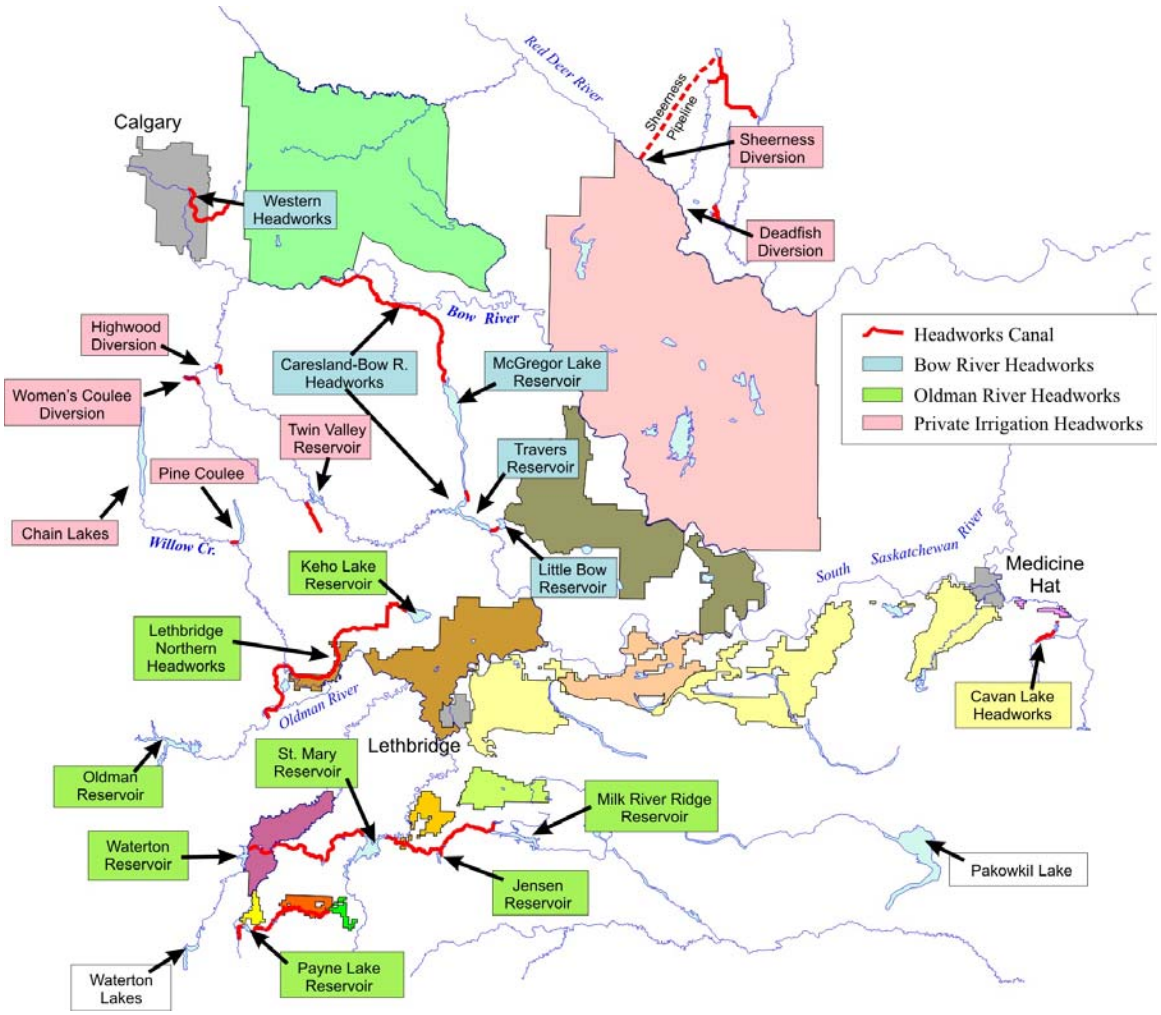

Figure 5: AENV water diversion and storage facilities supporting irrigation within the SSRB

With an estimated infrastructure replacement value of more than $3.5 billion, the irrigation districts have a most significant investment. There are more than 7,600 kilometres of canals, almost 4,500 kilometres in drains and 170 major water control structures.

Of the nearly three billion cubic metres of water storage capacity in AENV and irrigation district reservoirs, almost 40 percent of that reservoir capacity rests within the works of the irrigation districts all of which is off-stream. Figure 6 provides a picture of where the more significant of the 40 or more irrigation district reservoirs are located.

Table 2-2: Summary of Extent and IRC Value of Irrigation District infrastructure (2007)**

Type of Works	Construction Type	Length (km)	IRC Value ($ x 1000)
Conveyance	Open Channel – Unlined	2,763	$885,593
	Open Channel - Lined	1,978	$960,174
	Pipeline (Closed or Open)	2,934	$772,655
	Sub-Total	**7,675**	**$2,618,422**
Drainage	Constructed (Channel or Pipeline)	393	$21,357
	Natural Channel	4,073	$51,306
	Sub-Total	**4,466**	**$72,663**
Major Structures	Dams, dykes, control structures, etc.	**170 items**	**$834,361**
OVERALL TOTALS*		**12,141***	**$3,525,446**

** Total for length refers to accrued lengths of channel and pipeline works and does not include the total number of Major Structure units.*

*.** IRC refers to the Infrastructure Replacement Cost which is the estimated value of the works as if they were replaced in the given year of assessment (i.e. 2007).*

2.2.3 Water Licence Authorizations for Irrigation

Water licences issued for irrigation purposes, and more specifically for irrigation district use, are some of the oldest authorizations (more senior – highest priority) for water diversions in the province. Table 2-3 summarizes the licensed allocations according to irrigation district and the major river basin from which they draw their water.

Within Table 2-3, licensed allocations are separated into two columns based on the period of time which the respective allocations were made and priorities assigned. The significance of making the separation at 1991 is to reflect the major updating of maximum water allocations for irrigation purposes within the SSRB by AENV. This initiative is explained further in Section 2.4. Some irrigation districts have had licences amended in recent years, to reflect transfers of specific amounts of water to other users or have received additional allocations for new projects. These are detailed further in Appendix B.

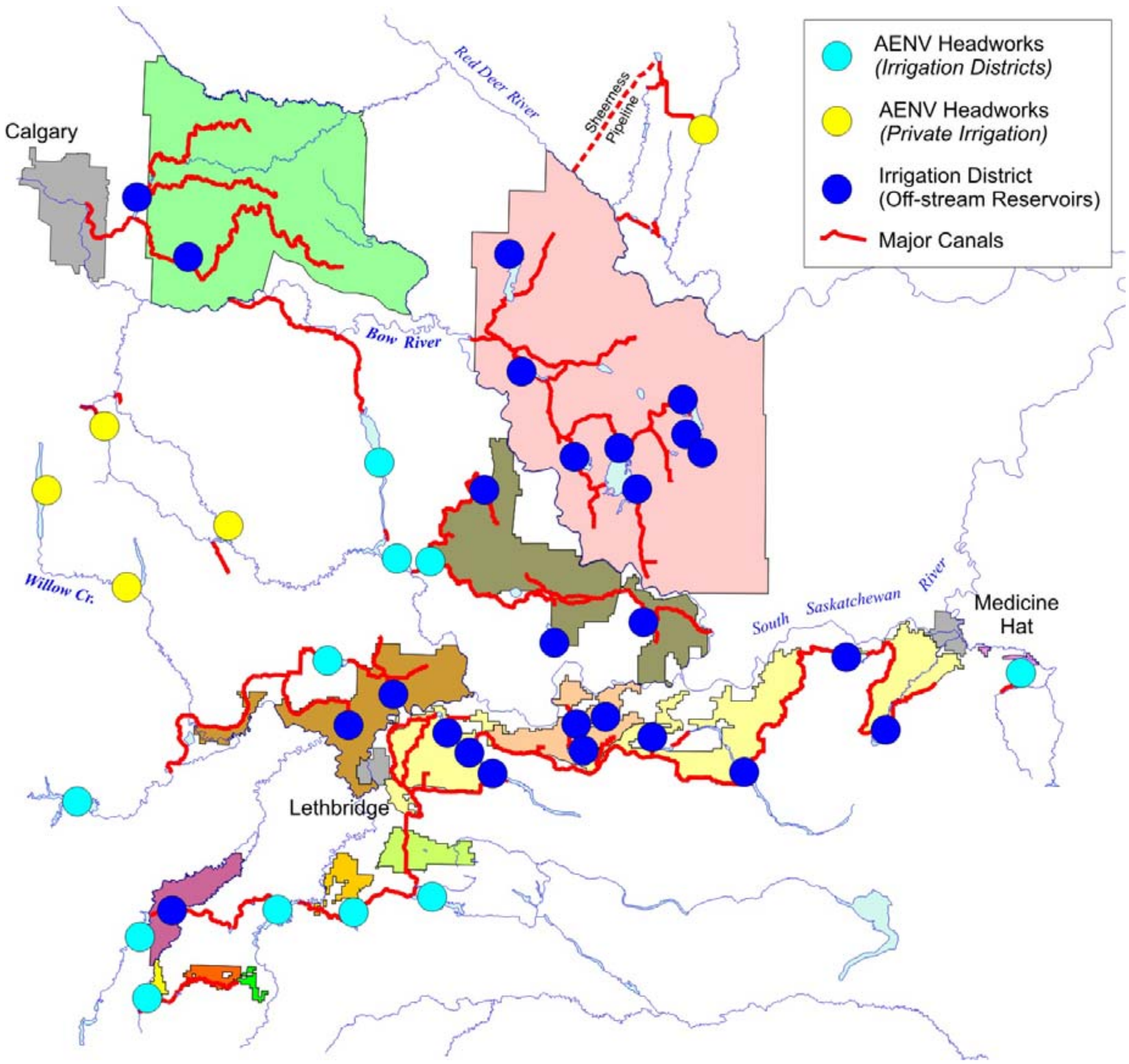

Figure 6: Location of AENV headworks and major Irrigation District reservoirs.

Figure 7 illustrates the proportional distribution of water allocations within the SSRB and MRB. Irrigation use is far and away the holder of the largest allocated volume. It is noted, however, that much of the unallocated 40 percent is committed to instream flow needs and inter-provincial and international apportionments. This graph is based on average annual natural flow.

Table 2-3: A Summary Listing of Irrigation District Licence Allocations and Priorities

Irrigation District	River Basin	Licence Volume (m^3) Pre-1991	1991 & later	Priority Date(s)	Licence Conditions
Aetna*	Oldman	6,784,398	4,317,344	1945, 1991	a & d
Leavitt*	Oldman	9,559,833	5,242,489	1939, 1991	a & d
Lethbridge Northern	Oldman	329,351,665	83,201,385	1917, 1974, 1982, 1991, 1995	a, d & e
Magrath*	Oldman	37,005,805	4,934,107	1899, 1950, 1991	a, d & e
Mountain View*	Oldman	9,251,451	616,763	1923, 1991	a & d
Raymond*	Oldman	67,843,976	32,071,698	1899, 1950, 1991	a, d & e
St. Mary River*	Oldman	616,763,418	273,842,958	1899, 1950, 1991	a, d & e
Taber*	Oldman	185,029,025	9,868,215	1899, 1950, 1991	a, d & e
United*	Oldman	62,909,869	18,762,338	1919, 1993	a, c, d & e
Sub-Totals		**1,324,499,440**	**432,857,297**		
Overall Total for Oldman Basin		**1,757,356,737**			
Bow River	Bow	468,740,198	86,346,879	1908, 1913, 1953, 1992	a, d & e
Eastern	Bow	939,947,449	0	1903	b, c & d
Western	Bow	197,857,705	-2,467,054	1903	a, b, c, d & e
Sub-Totals		**1,606,545,351**	**83,879,825**		
Overall Total for Bow Basin		**1,690,425,176**			
Ross Creek	South Saskatchewan	3,700,581	0	1951	n/a
Sub-Totals		**3,700,581**	**0**		
OVERALL TOTAL FOR THE SSRB		**3,451,482,494**			

Licence Conditions: (Source: AENV)

a) Permitted to use return flow from the district

b) Diversion timing conditions are included

c) Diversion rate restrictions can be imposed

d) Diversions are subject to satisfying minimum in-stream flow requirements.

e) Additional conditional diversions may be permitted under specific situations.

** Indicates those districts obtaining water from the St. Mary, Belly and Waterton Rivers.*

Table 2-4 summarizes the private irrigation projects across Alberta. On average, across the 543 projects listed as operating within the basins other than the SSRB and the MRB, the annual allocation for these equals an amount equivalent to a depth per unit area of 243 millimetres. Private irrigation average allocated depth is 315 mm in the SSRB and MRB due to less precipitation and higher heat units. The equivalent allocation for the irrigation districts, where weather, and storage, conveyance plus return flow losses are much more significant factors, averages approximately 615 millimetres. The difference between private and irrigation district depth of water in the SSRB is attributed to losses incurred delivering the water from the source-river to the irrigators.

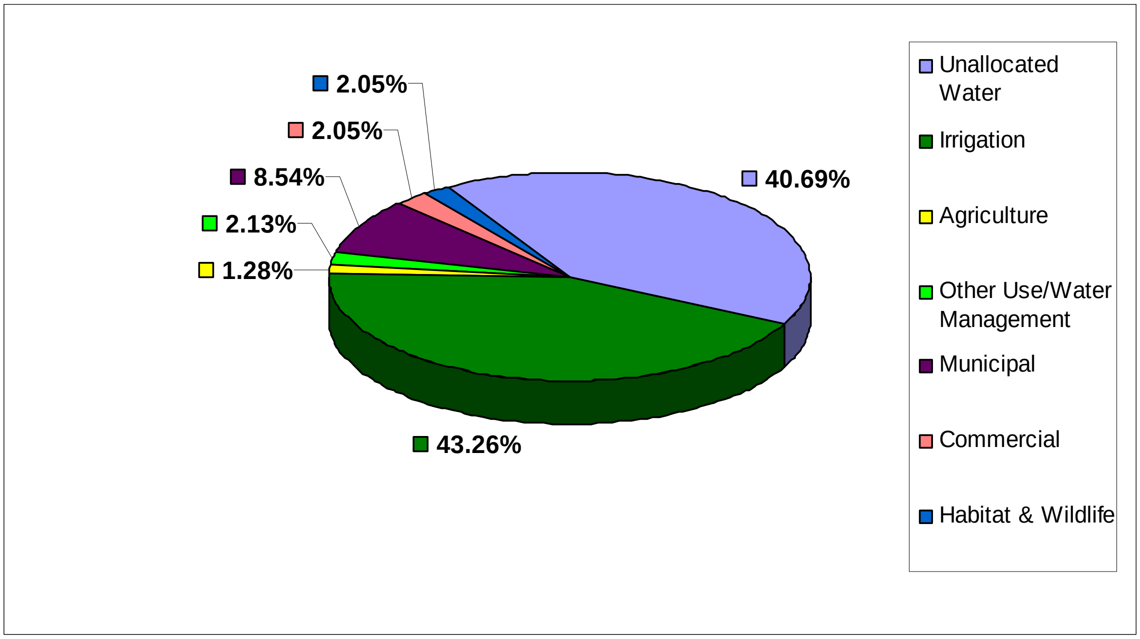

Figure 7 : Proportional amounts of allocated and unallocated water in the SSRB & MRB in an average runoff year. (Source: AENV State of the Environment)

Table 2-4: A Summary Listing of Private Irrigation in Alberta (2007)

River Basin	No. of Licenses	Allocated Volume (Million m^3)	Irrigation Area (ha)
So. Sask.	**2280**	322.39	**104,413**
Milk River	**112**	29.87	**7,618**
Athabasca	48	3.82	896
Beaver	6	0.18	89
North Sask.	397	26.20	11,410
Peace	81	3.37	1,417
TOTAL	**2,924**	**385.83**	**125,843**

2.2.4 Irrigation Water Use

The irrigation districts, in collaboration with AARD and AENV, have compiled a significant amount of historical data with respect to their actual water diversions and use. As a result, it's possible to perform a reasonable degree of analysis and carry out projections on future water use.

Figure 8 shows the historical relationship between irrigation district allocations, actual water use and growth in actual irrigated area. In particular, the significant licence allocation amendments of 1991 can be observed. Actual water use by private irrigators was not adequately documented until very recently as a more sophisticated reporting system has been implemented. The data collected to date, though, is too limited to determine any use patterns.

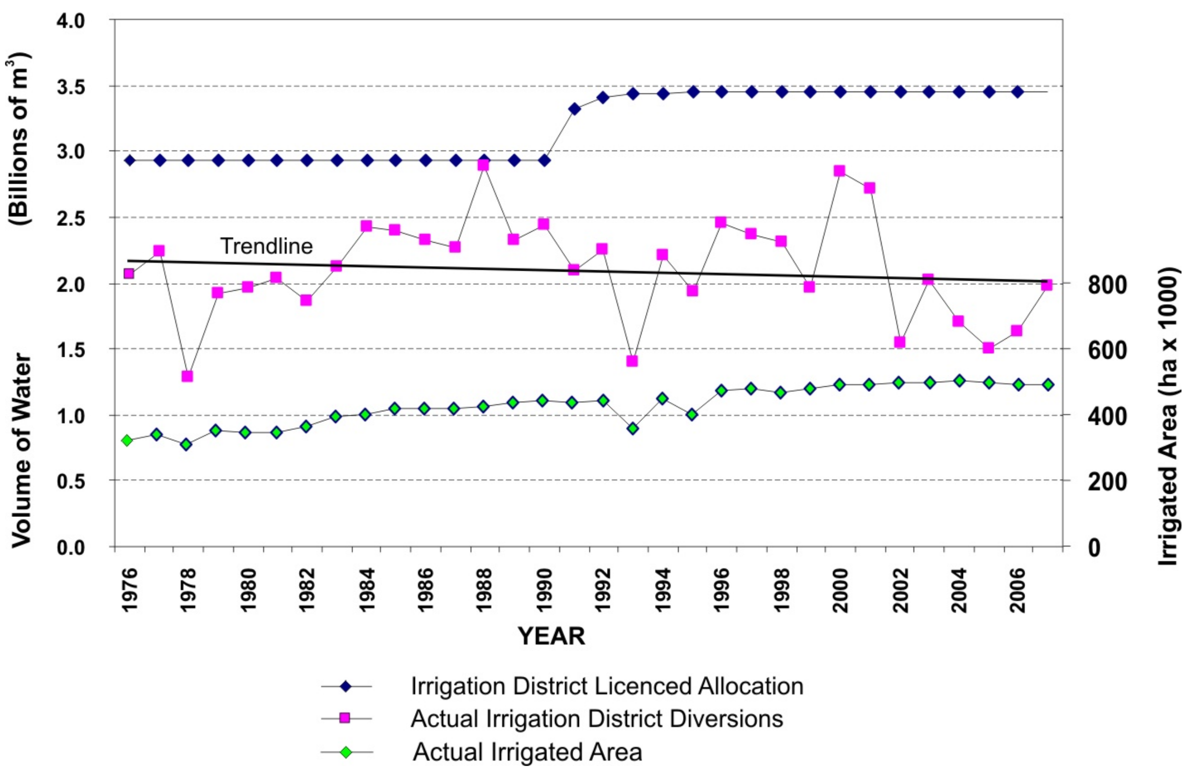

Figure 8: Irrigation District Licensed Allocations, Actual Irrigated Area and Diversions – 1976 to 2007 (Source: AARD Annual Irrigation Information and AENV State of the Environment)

Irrigation water allocations were originally determined on the basis that the allocated volume would be sufficient to meet irrigated crop and distribution operational needs 90 percent of the time for an assumed maximum irrigated area. At the time of licence issuance, the allocated volume of water was based on the irrigated acreage for which the district was designed. The principles applied in this regard are discussed further in Appendix H. Through to the early 1990s, many irrigation districts had not developed to their maximum size as allowed in the 1991 *South Saskatchewan Basin Water Allocation Regulation*. Further, not all irrigated fields are cropped in such a way as to require irrigation each and every year. As a result, in the majority of years, the irrigation districts' total diversion demand is notably less than the allocation, usually as a result of the vagaries of weather. This is reflected in Figure 8.

On average, relative to the current total licensed allocation (year 2007), the gross irrigation diversion demand at the point of diversion has been approximately 66.4 percent of the allocation under the Water Act, varying from about 41 percent in 1978 to 83 percent in 1988. It is to be noted that the volumes indicated include volumes diverted on behalf of other licensed water users and return flows. The current trend appears to indicate overall slightly decreasing volumes of diversion with time, despite the slow but steady increase in area under irrigation.

An alternative approach to analyzing the historic diversion trend, relative to irrigated area growth, is to determine the annual water diversion per unit area of actual irrigation in each respective year. This is depicted in Figure 9, where the downward trend line is much more apparent. The "proportional license allocation" curve represents the equivalent depth of water allocation per unit area of irrigation assessed to receive water. As the irrigation area has expanded through time, even though licence allocations have increased, the allocated water available per-unit area of irrigation has declined significantly during the past 30 years, as reflected in the overall downward curve.

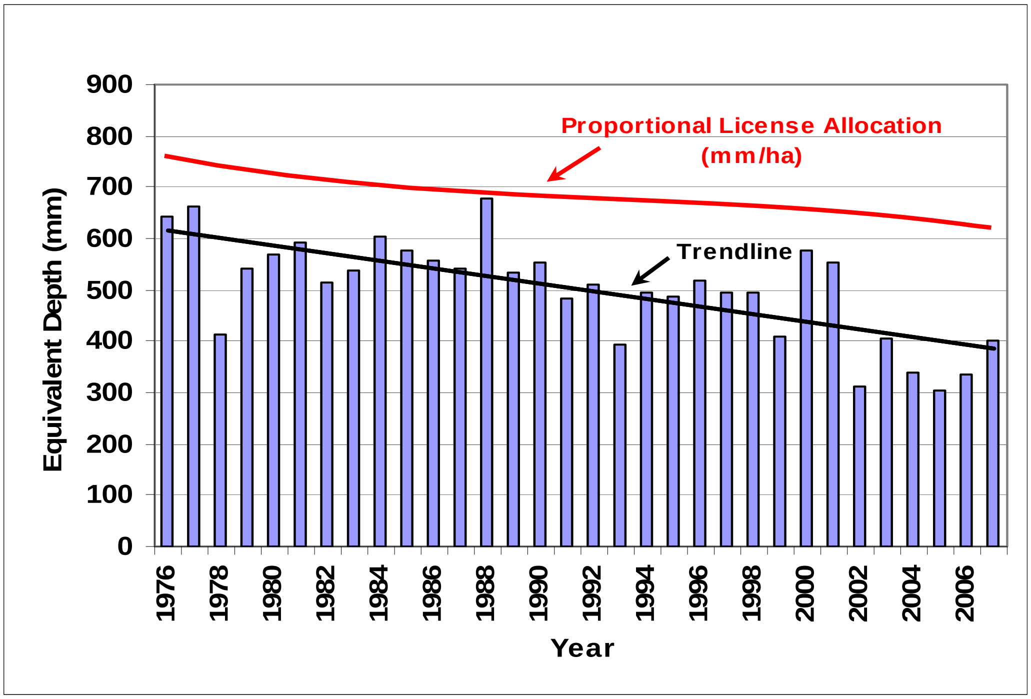

Figure 9: Trend Line Shows Decreasing Irrigation District Water Diversions Expressed as an Equivalent Depth of Water Diverted per Actual Unit Area Irrigated. (Data Source: AARD Annual Irrigation Information - 2007)

2.2.5 Issues Surrounding Return Flow

Since the mid 1990s, on the part of many of the districts, there has been a much more concerted effort to monitor return flows from their distribution works. Sufficient data has been obtained, compiled and analyzed, in collaboration with AARD, to derive some general characteristics of the current state of return flow volumes.

In Figure 10, return flow is expressed as an equivalent depth of water relative to the total area actually irrigated in each year, during the period 1997 through 2007. During that period, there was some on-going growth in irrigated area, but the associated distribution of return flow volumes over an increasing irrigated area is only a small factor in contributing to the declining amounts indicated by the downward trendline. The more significant contributor is a real and continuing reduction in overall return flow volumes, a decreasing trend averaging about a four-percent reduction per year.

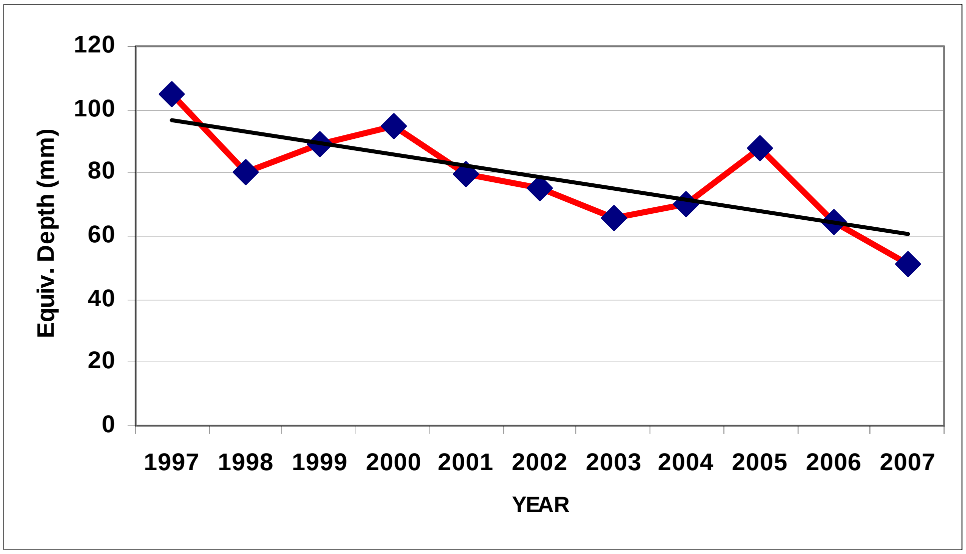

Figure 10: Irrigation District Return Flow Expressed as an Equivalent Depth Relative to Total Area Actually Irrigated. (Data Source: AARD)

Return flow volumes are often expressed as a percentage of the gross diversion of water into a system. In high demand (dry) years, this percentage can be somewhat less and in low demand (wet) years, it is somewhat more due to precipitation events which result in irrigation water being passed, unused, through the system and the additional water from rainfall runoff entering the system and also flowing into return flow channels. Records indicate that, as a percentage of the total diversion amount, return flow has remained more or less constant at about 19 to 20 percent, although the volume of return flow has decreased in pace with the reduction of water diverted.

An issue that has been debated is how to assess return flow relative to conservation, efficiency and productivity. As return flows are reduced, it can be concluded that less water is being extracted from the rivers, allowing water to be *conserved* by leaving it in its natural environment. On the other hand, water in irrigation district return flow channels is utilized. For example, prior to returning to the natural stream, return flows are often used to create or supplement waterfowl habitat or wetlands. There may be a *productivity* contribution where water users withdraw water from return flow channels or to the environment where return flow creates or enhances wildlife habitat.

There is also the consideration of the effect of return flow on the water quality of receiving streams. Studies (AARD 2008 and Bennett et al 2000) indicate that the quality of return flows can range between good and poor, depending on the criteria being applied (e.g. irrigation use, domestic use, etc.). It has been reported that return flow quality can have both negative and beneficial effects on the receiving streams (Ontkean et al 2000).

2.3 Linkages with Other Water Use Operations

While the irrigation industry consumes the largest amount of water in the SSRB and MRB, it is not the only sector that has significant impacts on water operations. As well, basin operations are becoming increasingly linked and complex. For example, no longer can a diversion from the Belly River at Mountain View operate independently from consideration of its impact in managing flows along the Bow or Red Deer Rivers. This point is illustrated in Section 2.3.2 to show how the inter-connections of operating dams and diversions are linked throughout the watershed and along the course of the river.

2.3.1 Multi-Purpose Water Use of Irrigation District Works

Many other water users benefit from being able to extract their water from or through the distribution works of the irrigation districts. Although these supplementary diversions may be small, relative to the irrigation component, they are usually included in the overall diversion volumes attributed to irrigation. Therefore, actual irrigation use values are slightly less than the amounts typically reported. While their direct volumes may be small in the overall picture, it is worth noting the extent to which these secondary diversions add to quality of life, economic development and environmental enhancements in the southern Alberta region. Towns like Taber, Vauxhall and Bow Island, industries such as oil and gas, food processors, wetland habitat, livestock feeding operations, domestic users, water cooperatives, reservoir fisheries and the like, all benefit from being able to access water from the works of irrigation diversion, supply and conveyance systems. This multi-purpose access to water is also revealed, for example, through the 33,000 hectares of wetland that have been developed by Ducks Unlimited, in cooperation with eight of the larger irrigation districts.

Table 2-5 summarizes some of the other water users that depend on irrigation diversions and conveyance works for their water supply, including an indication of their annual water withdrawals during 2007. The sum of these volumes, approximately 165 million cubic metres, is equal to more than eight percent of the total “irrigation diversion” for the 2007 operating year. Table 2-5 summarizes the volumes of water supplied to numerous small volume users, within the districts’ licensed allocations, as *alternate uses*, and the volumes also conveyed to a variety of other users who retain their own individual licences. A more detailed district-by-district summary is provided in Appendix E

Table 2-5: Summary Listing of Other Water Users Accessing Water Supplies Through Irrigation District Diversions, Including their Respective Withdrawal Volumes for 2007

Volume of Water Supplied for Alternate Uses (m^3) from Irrigation District Licences			
Municipal	**Industrial**	**Environmental incl. Wetland**	**Other Agricultural**
4,019,000	453,000	22,655,000	15,494,000
Volume of Water Conveyed for Other Licensees (m^3)			
Municipal	**Industrial**	**Environmental incl. Wetland**	**Other Agricultural**
19,410,000	17,225,000	63,430,000	22,111,000

Figure 11: A typical Ducks Unlimited and irrigation district wetland development.

2.3.2 Examples of Inter-Connectivity of Basin Water Management Operations

AENV and the Water Survey of Canada have installed instrumentation throughout the SSRB to provide real time data and a historical record of precipitation, snow pack, reservoir levels, river flows and river diversions. This data allows AENV to supply operators of various water control and diversion systems with long-term forecasts of the available supply based upon snowpack. In times of significant rainfall events, AENV will generate flood forecasts to allow dam owners and emergency responders to make preparations to ensure public safety. The various major water control, diversion and conveyance systems also have their own internal monitoring capabilities that provide a picture of the operating conditions at any given time.

AENV maintains an overview of basin flow regulation and diversion operations and sees that licence conditions and commitments to all water users are met and inter-provincial water obligations to Saskatchewan are honoured (see Section 2.4). Where there is a risk of insufficient water being available to meet the licensed allocations of more senior (higher licence priority) water users during the course of an operating period, junior or lower priority users may be required to cease withdrawals until the more senior rights are satisfied.

Reference to Figure 12 accompanies a simplified overview example of the challenges of effective and balanced water management within the Bow Basin. From the headwaters and following the river channel to its confluence with the Oldman River (where the two become the South Saskatchewan River), there is a complex system of linkages, occurring on a basin-wide basis, that need to be made among those responsible for managing various operational components within the system and for the protection of the aquatic environment.

TransAlta Utilities (TAU) operates several diversions and impoundments for the purpose of generating hydro-electricity. Their works do not consume water but do capture spring and summer flows for later release to produce hydro-electric power in the winter. TAU's storage works do withhold a significant volume of spring and summer flows of the Bow River. The Bearspaw reservoir, located on the Bow River just above the City of Calgary, serves multiple purposes. Not only does it retain water for electrical generation, it also acts as a balancing pond and smoothes-out fluctuations in river flow caused by TAU's upstream reservoir discharges, released through hydro generators to meet peak power demands. The Bearspaw facility maintains a constant downstream river flow, which helps to reduce problems with winter ice jams through the City of Calgary.

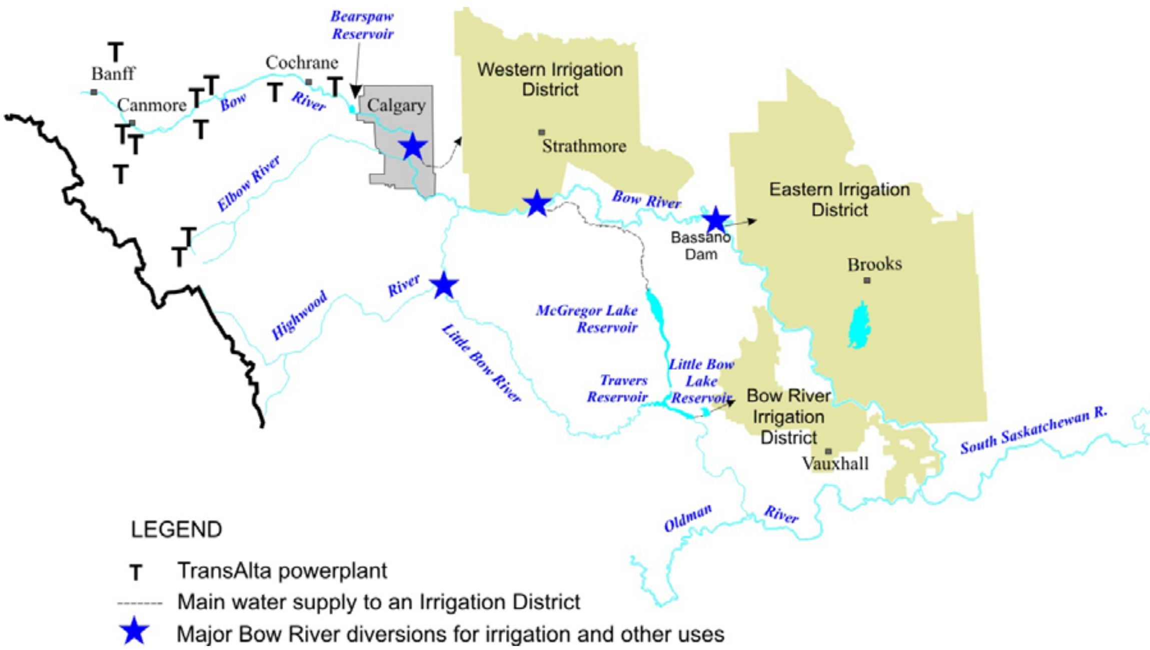

Figure 12: A conceptual illustration of the major water diversions and use in the Bow River Basin.

The next major user along the Bow River is the City of Calgary. While TAU's operations withhold but do not *consume* any water, Calgary's operations do. However, the City does return 90 percent of the water it diverts. The quality of Calgary's return flow water has been an issue in past years, particularly in regards to its impact on the Bow River aquatic environment and on accelerated weed growth in downstream irrigation district canals. It has been steadily improving since the 1980s but so is Calgary's population so nutrient loadings to the river can still be above desirable levels.

The irrigation districts relying on water supplied from the Bow River are the Western, Bow River and Eastern, with river diversions at Calgary, Carseland and Bassano, respectively. The districts consume a considerable percentage of the water diverted but have returned a reasonable proportion, as well, in the form of unused flow. In more recent years, these districts have been able to significantly reduce their return flows due to the on-going on-farm conversions from surface ("flood") irrigation to sprinkler methods and the modernization of district conveyance systems since the 1970s.

Once water enters the irrigation conveyance systems, it provides many beneficial uses beyond crop irrigation. Water stored in off-stream reservoirs allows for water-based recreational use, fish and wildlife habitat, commercial fisheries and encourages adjacent cottage developments. Irrigation supply canals and pipelines convey water to many different users such as municipalities, industries, thousands of individual domestic users, and livestock operations. The municipalities of Strathmore, Vauxhall and Brooks, among others, obtain their water supply through irrigation works.

The province monitors flows in the Bow and Oldman Rivers carefully to ensure an adequate flow reaches the City of Medicine Hat and other water users along the South Saskatchewan River.

Flows in the Red Deer River are also observed and managed to ensure that the Province of Saskatchewan receives its share of the South Saskatchewan River Basin water in accordance with an inter-provincial agreement, overseen by the Government of Canada.

The accrued demand for water in much of the SSRB has now reached the available supply. As a result, applications for new water licences are no longer being accepted in the Bow and Oldman River Basins. Proper water management in the SSRB has become critically important.

2.3.3 Small Hydroelectric Development

One of the unique linkages to developed irrigation operations occurs within the Oldman River Basin water management infrastructure. In the past 10-15 years, a few irrigation districts and private corporate interests have developed facilities for small hydro-electric power generation, ranging in size from 2.5 to 32 megawatts. There are three such sites within the St. Mary Irrigation Project works, owned and operated by a three-district consortium known as Irrican Power, with a total capacity of just over 38 megawatts. In addition, there are five other installations within AENV headworks facilities with a total generating capacity of 53 megawatts. Three of the eight installations can operate year-round, as they are connected to on-stream dam low level outlets. The rest of these facilities can only operate while irrigation water is being conveyed (for 5-6 months). In order to make these facilities as cost effective as possible, there is a strong linkage between regulating flows to generate hydroelectricity, meet irrigation demand and manage reservoirs to optimize storage.

2.4 Review of Current Policies, Programs, Plans and Legislation

More than thirty years ago, during the planning phase for the development of a storage reservoir on the Oldman River, it was recognized that the water supply for irrigation and other uses was limited in the SSRB. In 1991, the Province approved the *South Saskatchewan Basin Water Allocation Regulation (the Regulation)*, which, for the first time, established limits to irrigation area growth throughout the SSRB and the amount of water volume that could be allocated to irrigation use.

Since then, the province has passed new legislation that directs the administration and management of the water resource (Water Act) and irrigation districts (Irrigation Districts Act). The Water Act has dramatically altered how new licences (and to some extent older licences) are administered. In particular, it includes provisions for establishing Water Management Plans, Water Conservation Objectives and for trading volumes of water allocated under existing licences.

2.4.1 Related Policies, Programs and Plans

The priority of water use remains based on the "first in time, first in right" principle. Regardless of the purpose of use, the higher priority during times of shortage goes to the more senior or older licence. However, when faced with critical water shortages in recent times, most affected water users have collaborated to develop mutually agreeable methods of water-sharing or temporary transfer processes that are permissible within the *Water Act*.

The *Irrigation Districts Act* (2002), with oversight through the Irrigation Council, provides measures that supersede the *Regulation*, allowing for expansion of an irrigation district's irrigated acreage, within its licensed water allocations. The major premise within the Act that opens the door to irrigated area expansion by an irrigation district is that its operations and water supply are such that any additional area to be serviced as an expanded irrigation area could be irrigated without any increase in risk to the new area or the previous irrigated area. Hence, where water-use efficiency gains and the associated water savings can be demonstrated and quantified to be adequate to meet the irrigation demands of the whole of an expanded irrigation area, expansion may be permitted. The Act specifies certain procedures that must be followed to validate the opportunity to expand, sustained by reliable water supplies (e.g. derived through improved water use performance), including a formalized acceptance by the existing irrigators within the irrigation district.

Since these new pieces of legislation were passed, two significant policy developments have occurred. First, Watershed Planning Advisory Councils (WPACs) have been established by the Province in many river basins throughout Alberta, to more extensively involve basin residents in local and regional water management deliberations. Secondly, the South Saskatchewan River Basin Plan (AENV 2006) was approved through an Order in Council. In the development of that plan, through a process of public education and debate, one component of that plan establishes further limitations on water development in the SSRB, to the extent that the province will no longer receive new applications for water allocations in the Bow and Oldman basins. Similarly, a ceiling has been set which, when reached, will signal that the Red Deer Basin should be closed to new licence applications, as well.

Other water management methods employed include water licence conditions allowing terms of water withdrawals to be amended on an annual basis, provided other licences and the environment are not negatively impacted, or stipulating minimum river flows at which point diversions must cease. An example would be where an irrigation district may apply, on an annual basis, to divert water prior to the start date specified in their licence. This is reviewed on a case-by-case, season-by-season basis by AENV and can be permitted for a one-year term. A typical justification of such a situation is where district internal reservoirs are at undesirable low levels and could be filled early in the year if sufficient river flow is available.

Another useful method for water management is the distribution of water held in on-stream storage reservoirs. The principle applied is that the reservoir owner may determine the purposes for which the stored water will be utilized. While licensees are entitled to their portion of the 'natural' flow, water released from storage in excess of the natural flow can be used for purposes that the Province, for example, as owner of an on-stream reservoir, feels is in the best interest of the public.

Other controls that can affect irrigation operations can include such regulatory tools as the Alberta Water Quality Guidelines, Alberta Environmental Protection and Enhancement Act and the federal Fisheries Act.

2.5 Irrigation Sector CEP Initiatives and Programs

The irrigation sector demonstrated significant improvements in its use of water, in terms of efficiency, conservation and productivity, prior to the implementation of Alberta's water strategy, "*Water for Life*" in 2005. The advancements started in a notable way in the early 1970s on two fronts - the application of water on the farm and the conveyance of water to the farm.

2.5.1 On-Farm Irrigation Improvements

Improved application of water on the irrigated fields can mean not only savings in water but the prevention of soil salinization and water-logging that can occur either through over-irrigation or through the irrigation of lands that, if today's strict land classification standards had been applied, would not have been allowed to have been irrigated in the first place.

As the on-farm component of irrigation water use within irrigation districts represents approximately 70 to 75 percent of the gross annual diversion volume, improvements in water use at the farm level can return the most significant gains in water conservation and in water use efficiency.

There are many factors that can affect the efficiency of on-farm irrigation (see Appendix F), but the type of system used to apply the water on the field is likely one of the most significant. Technology advancements that have led to labour-saving and reduced energy inputs have also provided higher application efficiencies. The shifts, since the early 1960s, from traditional or surface gravity irrigation ("flood") systems, to wheel-move side-roll sprinklers, to high pressure centre pivots and then to low pressure centre pivot systems have been a significant part of irrigation area growth, both within irrigation districts and to a greater extent within private irrigation projects. At the same time, on-farm irrigation water use efficiency has more than doubled, from less than 30 percent in 1965 to nearly 73 percent in 2007.

Figure 13 illustrates the growth in overall irrigated area during the past 42 years, in combination with the shift in on-farm methodologies for applying the water to the crops. In 1965, for example, almost 94 percent of the irrigated area was irrigated by various surface gravity methods, while wheel-move and hand-move sprinkler systems, etc. made up the small remaining balance of water application methods. By 1985, only 20 years later, gravity or surface irrigation was being utilized on less than 25 percent of the irrigation area while wheel-move and related systems had grown to represent coverage of almost 47 percent of the area. At the same time, use of centre-pivot technology rapidly expanded, beginning in the mid 1970s, covering nearly 29 percent of the total hectares of irrigation in 1985.

By 2007, of the total irrigation area across Alberta, the portion covered by gravity, wheel-move, etc. and centre pivot systems had shifted, respectively, to an estimated 12 percent, 18 percent and 70 percent proportional distribution. This shift in irrigation application methods has contributed greatly to the significant gain in on-farm water-use efficiency that has been accounted for during this development period.

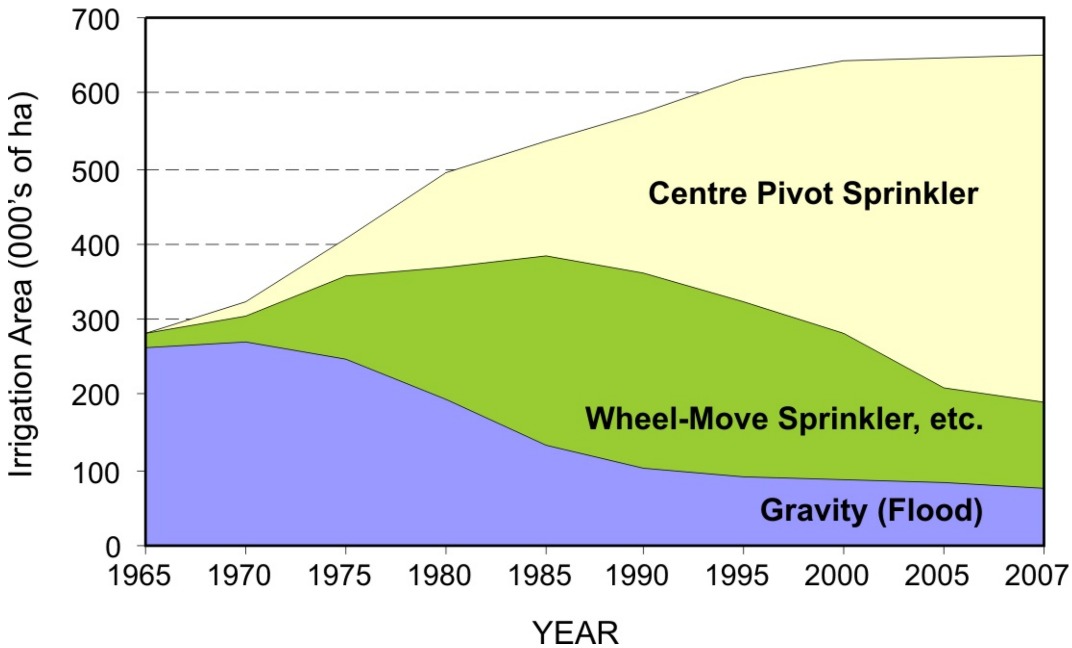

Figure 13: Historical Shift in On-farm Irrigation Methods and Proportional Growth within Alberta's Irrigation Districts. Data Source – AARD)

In determining the overall on-farm efficiency value, a nominal "on-farm application efficiency" value is referenced for each different type of methodology, ranging anywhere from 25 to 95 percent, depending on the type of irrigation practiced. These values have been pre-determined and selected as industry standards across many irrigation jurisdictions. (See Appendix F.)

Table 2-6 illustrates, in limited fashion, the results of the overall application efficiency determination process for all on-farm irrigation operations within the SSRB and MRB. With the irrigation area of each type of system known and by assigning the respective nominal application efficiency value for each system-type to those areas, an overall weighted-average efficiency value can be calculated for the entire irrigation area. The nominal efficiency values indicated in Table 2-6 have tended to change slightly with time as newer technologies in each category have been increasingly adopted. Annually, since about the year 2000, the irrigation district community compiles a very comprehensive inventory of all on-farm systems. This has enabled such a weighted-average efficiency determination process to be carried-out with reasonable accuracy. Records exist prior to 2000, but to a lesser degree of detail. Similarly, on-farm system-type coverage-area values associated with private irrigation projects are included as best estimates from periodic inventories assessed by AARD in the past. It is well-accepted that the proportion of centre pivot systems used has typically been somewhat higher in private projects than in irrigation district areas.

Table 2-6: A Summary Listing of Weighted-average On-farm Irrigation Application Efficiency Determinations for the SSRB and MRB.

Type of System	1980		1995		2005	
	Area (ha)	Nominal Efficiency	Area (ha)	Nominal Efficiency	Area (ha)	Nominal Efficiency
Centre Pivot	126,508	70%	293,956	73%	424,010	77%
Wheel-Move etc.	175,611	64%	226,211	67%	123,670	69%
Gravity	196,744	45%	98,789	50%	83,288	52%
Overall Efficiency	**58.0%**		**67.1%**		**72.1%**	

The increasing adoption of pumped sprinkler systems since the late 1960s and early 1970s enabled considerable areas of land to be irrigated that could not be irrigated by conventional gravity methods. This also allowed for the use of increasingly higher-efficiency sprinkler irrigation systems that were being developed. However, the move by irrigators to the newer, more water-use-efficient technologies was primarily driven by the need to increase the precision of water applications for crop productivity, to reduce costly and difficult-to-acquire labour requirements and to reduce energy consumption costs. Although there was always an inherent ethic by producers to save water resources, the over-whelming need to balance commodity returns with input costs was a primary driver in the decisions to adopt newer, more water-use-efficient systems.

One of the benefits to the move away from gravity irrigation and the adoption of the more efficient systems is not only realized at the point of diversion, with less water needing to be diverted per unit of irrigated area, but also in contributing toward reductions in return flow.

In recent years, some districts have used incentives to encourage conversion to higher efficiency systems. These incentives have been derived by either restricting the amount of water delivered to irrigated parcels to a specific amount each year or through providing financial incentives for irrigators to upgrade their on-farm systems, as offered in the Eastern Irrigation District (EID). In the case of the EID, the incentive program has reduced demand for water, permitting more efficient operations and cost effective expenditures in the re-development of delivery infrastructure to those farms and, in some cases, improving return flow management.

With the exception of some relatively minor financial assistance received as incentives by a small number of producers within EID, the capital cost of adopting, developing and implementing the upgraded systems has been borne entirely by the irrigation producers. It is estimated that during the period since 1965, producers in both irrigation districts and private projects have invested in excess of one billion dollars to acquire improved water application technologies.

2.5.2 Improvements in Irrigation District Conveyance

The primary “inefficiencies” within irrigation district conveyance systems involves water losses due to seepage from open channels (canals), the return flow inherent within any open conveyance system and, to a lesser degree, evaporative losses. In the early 1970s, the conveyance works of the irrigation districts, many of which were between 50 and 70 years old, were in a state of disrepair. Seepage losses and return flow volumes were significant.

In 1969, the Provincial Government of Alberta implemented a program of providing some funding to irrigation districts to begin rehabilitation of the worst of the deteriorated works. That program was expanded to provide annual funding and is known today as the Irrigation Rehabilitation Program (IRP). It continues as a cost-sharing program with the districts, where the latter contribute 25 percent of rehabilitation funds and the Provincial Government contributes 75 percent (Ring 2006). Since 1969, the Province has granted over $720 million, with the district irrigators contributing nearly $164 million. As of fiscal year 2008/09, the annual Government contribution is $28 million and the irrigation district portion is nearly nine million dollars (AARD 2008). Beyond the IRP contribution, irrigation districts have expended more than $100 million in carrying-out additional rehabilitation work. Further, AENV, under their previous Headworks Improvement Program, contributed about $200 million, to fund a limited number of special projects for the rehabilitation of large district-owned irrigation works.

Government or public funding to this rehabilitation work has been determined to provide capital support that pays significant economic dividends to the Alberta and Canadian public, while also enabling more efficient use of water and elimination of degradation to adjacent lands through seepage prevention. The IRP funding has been distributed proportionately between all the irrigation districts primarily based on a formula which considers the amount of area irrigated and the capital value of the infrastructure of each district. The administration of the funds and approval of projects is overseen by the Irrigation Council.

The result of this substantial investment in the rehabilitation of irrigation district infrastructure has been significant. Canals have been upgraded and, where required, lined with membrane liners to preclude seepage losses and the resultant damage to adjacent fields. Pipelines were introduced in the early 1980s, beginning the conversion from open channels to closed pipe systems. The pipe industry's ability to produce cost-effective, large diameter pipelines in the early 1990s increased the size of open channels that could be converted to pipeline. Pipelines became the option of choice in most canal rehabilitation. Table 2-7 summarizes the extent of irrigation district works that have been rehabilitated by construction-type and the extent of those works that remain to be rehabilitated.

Table 2-7: Summary of Progress in Irrigation District Conveyance Works Rehabilitation. (Data Source: AARD - Alberta Irrigation Information – 2007)

Conveyance Works Type	Length of Works (km)	Proportion of Total Length of Works
Earthen Canals	1,416	18.56%
Membrane-Lined Canals	736	9.64%
Concrete-Lined Canals	144	1.89%
Sub-Total	**2,296**	**30.09%**
Open Pipelines	176	2.31%
Closed Pipelines	2,759	36.16%
Sub-Total	**2,935**	**38.46%**
Un-Rehabilitated Canals	2,400	31.45%
TOTAL Conveyance	**7,631**	**100.00%**

The rehabilitation of irrigation works has allowed substantial improvements to the water conveyance operations of the districts. With the allocations of irrigation water being adjusted during the course of establishing "*The Regulation*" in 1991, it was projected that conveyance losses in the future would diminish to equate to about 10 percent of the gross diversion. Field research tests carried out by AARD in 2000 (IWMSC 2002) determined that the actual loss due to seepage from the rehabilitated open channel conveyance works was only approximately 2.5 percent of gross diversion. In addition to these losses, open channel conveyance is also subject to evaporative losses, but these are understood to equate to only about 0.5 percent of the gross diversion volume. As open channel reaches are reduced or eliminated, evaporative losses are reduced proportionately.

Substantial seepage and evaporative loss reductions have been gained through the high proportion of installed pipelines (i.e. 38.5% of total conveyance length). Closed pipelines, in particular, have significantly influenced the reduction in return flows, particularly in district systems with multiple downstream reservoirs that serve as balancing or detention ponds.

Improvements to conveyance works have also reduced the potential for deteriorating soil conditions in adjacent or downslope lands, to the point where much of the earlier salinized or water-logged lands have been reclaimed.

Losses from reservoirs are almost exclusively attributable to evaporation. Depending upon the nature (e.g. depth and seasonal water temperature) of any given reservoir, it has been estimated that, in southern Alberta, anywhere from one-half to almost one metre of water can be lost due to reservoir evaporation each year. This translates into approximately 3.0 to 3.5 percent of the gross diversion into and through such reservoirs. As there are no means to practically reduce reservoir evaporation, this loss component will continue to exist.

2.5.3 Overall Improvements in Irrigation District Water Use Efficiency

In assessing the progress of water use efficiency by the irrigation sector, or at least by the irrigation districts, the collection and compilation of various data during the past 40 years, or so, has enabled the development of the conceptual graphs illustrated in Figure 14. The blue line indicates the significant efficiency gains that have been achieved on the farm side. The change in efficiency from 1965 to 1980 can be attributed to the shift from surface (flood) irrigation methods to sprinkler irrigation practices, primarily side-roll wheel-move systems. The continued rise in efficiency after about 1980 reflects the growing acceptance of centre pivot irrigation, while the efficiency increases being realized after 2000 reflect the increasing adoption of low pressure centre pivot sprinklers. The blue line plot presents the on-farm efficiency as that component of the gross diversion that is actually delivered at the farm gate and shows an improvement of 29 percent to 72 percent. As an important point of interest, were the overall efficiency computed relative to the total gross diversion (red line), there is seen to be a greater than four-fold improvement (12 percent to 54 percent). This is explained further in Section 3.1.2.

Deriving the component efficiencies can be a complex process. For example, surface (or flood) irrigation dominated the on-farm methodologies used in the earlier years leading up to the mid-70s. Those inefficient practices typically generated a good deal of run-off or tailwater that generally ended-up as a part of the delivery system return flow. Therefore, the results of on-farm inefficiencies were also showing-up as return flow “losses”. It is important to minimize any possible double-counting of water use inefficiencies.

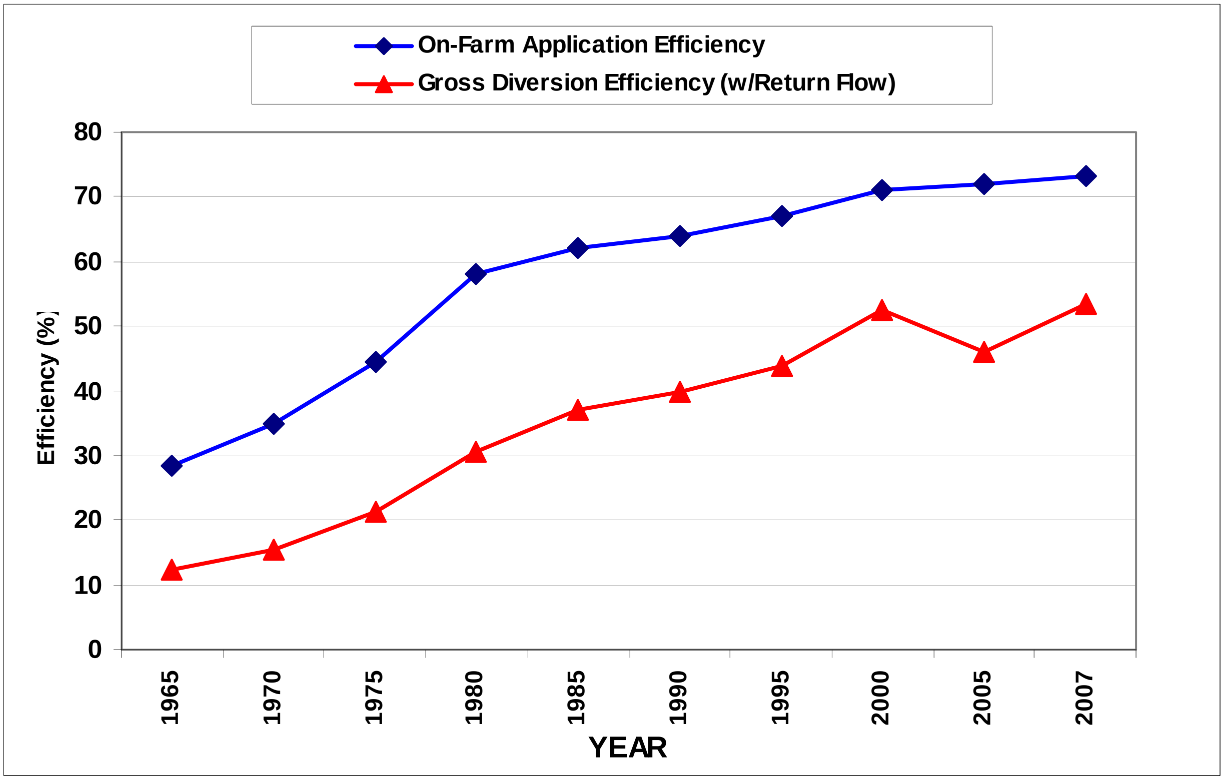

Figure 14: Historical Overall Gains in Irrigation Water-use Efficiency within Alberta's Irrigation Districts. (Data Source – AARD)

Figure 14 also indicates that the rate of gain is tending to level off as the better technologies become more widely adopted in the last 15 years or so. This may suggest a limit to what realistically may be achieved in improvements to on-farm efficiencies, at least with the currently available technologies.

2.5.4 Developing an Assessment of Productivity Gain

Assessments as to irrigation productivity outcomes from the use of water can be both quantified as measurements in terms of actual outputs per unit of water diverted and qualified as to perceived benefits to society and improvements to quality of life. Irrigation productivity can be expressed relative to the value of irrigated production or the value-adding that can be attributed to that production (e.g. food processing). Further, if the irrigation sector is able to transfer saved water through efficiency gains to the irrigation of additional land areas, without increasing the risk of water shortages, this measurement could also be an indicator of productivity gain.

The socio-economic and environmental benefits that accrue from improved access to or utilization of water that has been saved through greater water-use efficiencies within the irrigation sector are measured through direct productivity outputs from the irrigation sector. The development of more wetlands or other habitat, utilizing irrigation diversions or return flows, are examples of potential benefits that may be derived through more efficient irrigation water use. However, these are not measures of irrigation productivity, but could more likely be measures of increasing environmental vitality.

It is also important to recognize the implications and limitations of the irrigation sector holding senior and large quantity water licences. In most cases, any significant and consistent benefit to other users, from water savings derived through improved irrigation operations, will be reliant on the irrigation sector's interest, willingness and ability to actually transfer water-saving portions of its allocated water to other users, particularly within closed river basins.

With regard to direct irrigation production and productivity measurement, AARD has developed a form of productivity index that tracks the recorded annual yields of three major crops unique to irrigated lands in southern Alberta. These are sugar beets, potatoes and soft white spring wheat. It has been proposed that this be used as one indicator of irrigation productivity increases. By integrating the annual volume of water diverted (Gross Irrigation Diversion Demand at the water source) for use by each crop with its respective yield for a given year, an average output for the three crops per unit of water input is developed. This indicator, as depicted in Figure 15, has been derived as a productivity index for 27 of the past 28 years.

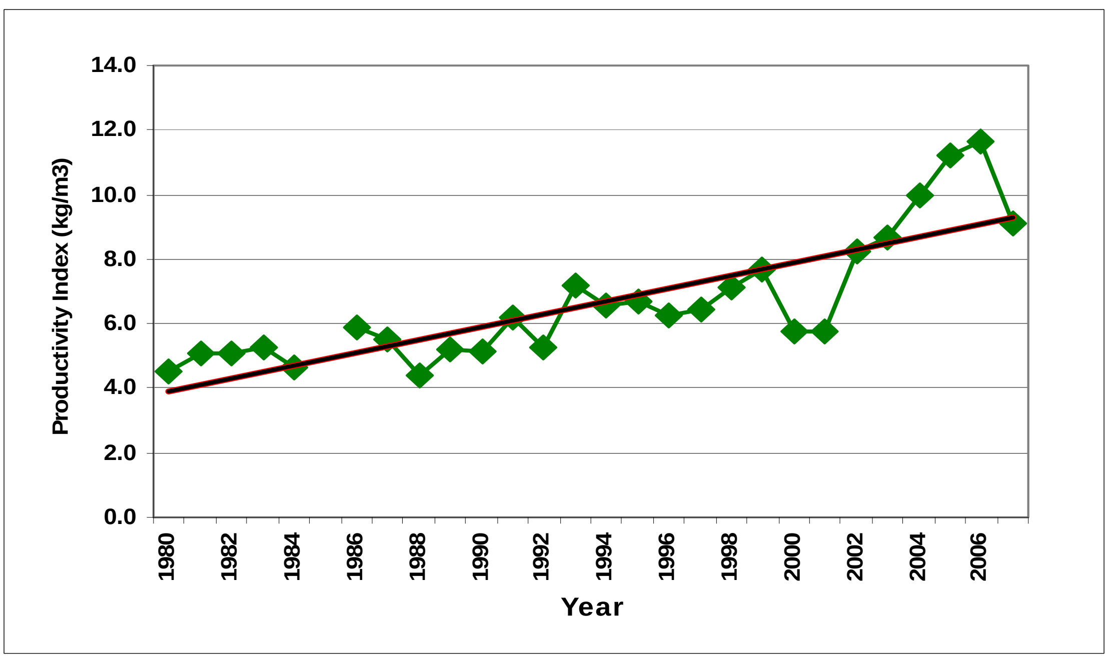

Figure 15: An Example of Quantifying Irrigation Water Productivity through Increasing Crop Production for Combined Production (kg) of Sugar Beets, Potatoes and Soft White Spring Wheat per m^3 of Water Diverted at the Source. (Data Source – AARD)

As can be seen, the trendline for this index indicates an on-going increase in water use productivity at an annual rate of approximately 0.2 kilograms per cubic metre of water per year. This increase is the result of more efficient and productive use of applied water and overall improvements in crop production practices.

The economic value of primary production on irrigation land in Alberta can be as much as four to five times greater than that of dryland agriculture, as documented in Volume 5 of the "*South Saskatchewan River Basin – Irrigation in the 21st Century*" reports, produced by the Irrigation Water Management Study Committee (IWMSC) in 2002. As a result, the transfer of conserved water to an appropriate area of new irrigation land can result in significant productivity gains. Accordingly, an area expansion of 0.4 percent per year could yield a 1.5 to 2.0 percent increase in productivity per year, relative to dryland production. (See Section 4.3.1 for the 0.4% rationale.) This includes not only the increased value of the primary production but the benefits of the value-adding and employment linkages that accompany irrigated agriculture.

3. Water Supply and Demand Considerations for Irrigation

Water management within the broad context of the SSRB is complex. Managing water within the irrigation sector has added complexities due to the many and diverse variables impacting its operations. As a result, forecasting irrigation water demand and supply can often be more of an art than a science and benefits from the forecaster's familiarity with the subject.

Much of the information presented in this chapter is derived from the extensive development and analyses work carried out by AARD in collaboration with Alberta's irrigation districts and AENV. This work has been reported in the "*South Saskatchewan River Basin – Irrigation in the 21st Century*" reports produced by the Irrigation Water Management Study Committee (IWMSC) in 2002.

3.1 Irrigation Water Demand Forecasting

In order to generate effective projections for water use, it is necessary to look at past, present and future aspects of the irrigation sector, including such things as:

a) continued growth in irrigation area within existing water allocations;
b) increased optimization in meeting crop water requirements;
c) shifts in cropping patterns as influenced by market conditions;
d) continued conversion of on-farm water application methodologies; and
e) continued improvements in diversion, storage and conveyance infrastructure

3.1.1 Forecasting Methodology – Trend Analyses

Irrigation districts can expand their irrigation area, subject to conditions within the Irrigation Districts Act. Between 2003 and 2006, five districts have exercised that option, expanding their collective irrigation base by 25,500 hectares. For those five districts, this represents a growth of approximately 9.5 percent. Relative to the irrigation area of all 13 districts, this equates to an expansion of about 4.8 percent. A couple of other irrigation districts proposed expansions of five to ten percent, but these did not proceed due to the lack of approval from their irrigators. While there is some interest to see expansion of irrigated acreage, it appears that, in the near future, any growth in irrigation area will be minor. Existing irrigators have concerns that expansion may result in an unacceptable increase in the risk of water shortages.

In Chapter 2, Figure 8 indicates that the trend in irrigation water diversions is slowly but continuously declining. This is even more evident when assessing diversions on an irrigated area unit basis (Figure 9).

As irrigation water demand is closely linked to crop growing-season precipitation, it can be questioned whether this downward trend is more a reflection of higher precipitation conditions in recent years. In examining that question, the annual unit area demand for water is compared with the trend in seasonal precipitation. As can be seen in Figure 16, the recent historical precipitation trend line within the irrigated areas has been flat, while the trend in annual water use per unit of irrigated area is seen to be decreasing at an average rate of nearly 8 millimetres per year or by 1.2 percent per year for the past 30 years.

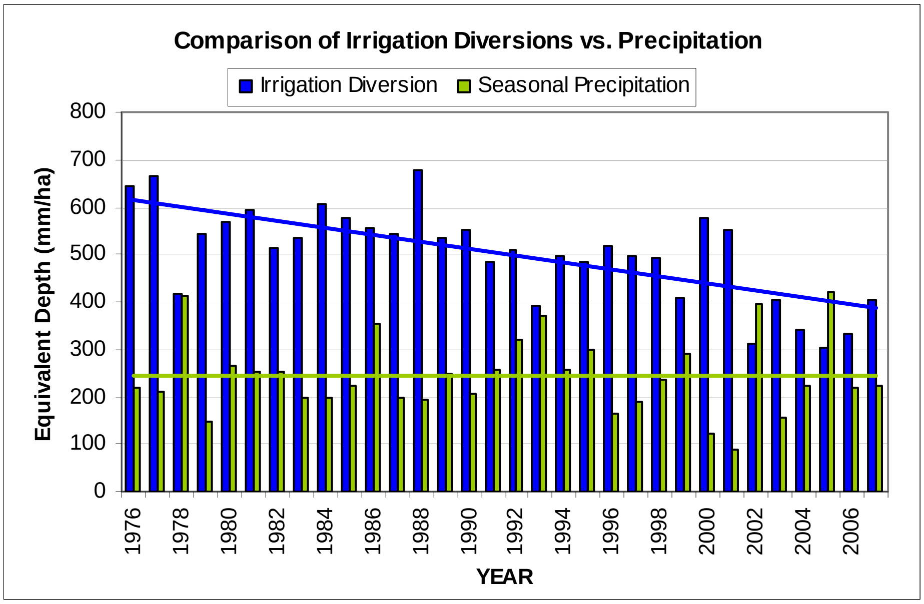

Figure 16: Irrigation Water Use Trend in Comparison with Crop Growing-season Precipitation Trend

Assuming all other factors such as climate, cropping practices and management patterns remain more or less constant, the on-going improvements at the farm and distribution system levels would be expected to continue to effect further reductions in water use, per unit of irrigated area. However, the current rate of decline will not be sustainable through the long-term. As efficiencies reach a practical optimum level, the fundamental requirement to meet crop water requirements will tend to flatten the downward trendline.

While annual water use has been decreasing, a change in crop mix as also occurred. Figure 17 shows the difference between year 1997 and 2007. Producers moved away from typically low-valued grains to higher-return forages, oilseeds and specialty crops. Shifting to more area under forage varieties does not necessarily equate into higher water use, as lower water consumption crops such as barley-silage are considered forage. Similarly, growth in the irrigation of specialty crops does not necessarily translate into higher water use either as certain specialty crops, such as field beans, are relatively low water-use crops. It is believed that, in the future, producers will likely optimize water applications for maximum economic yields, potentially resulting in slightly higher levels of irrigation water use. It is conceivable that a crop mix shift, as indicated in Figure 17, could result in a net increase in water requirement of between three and five percent.

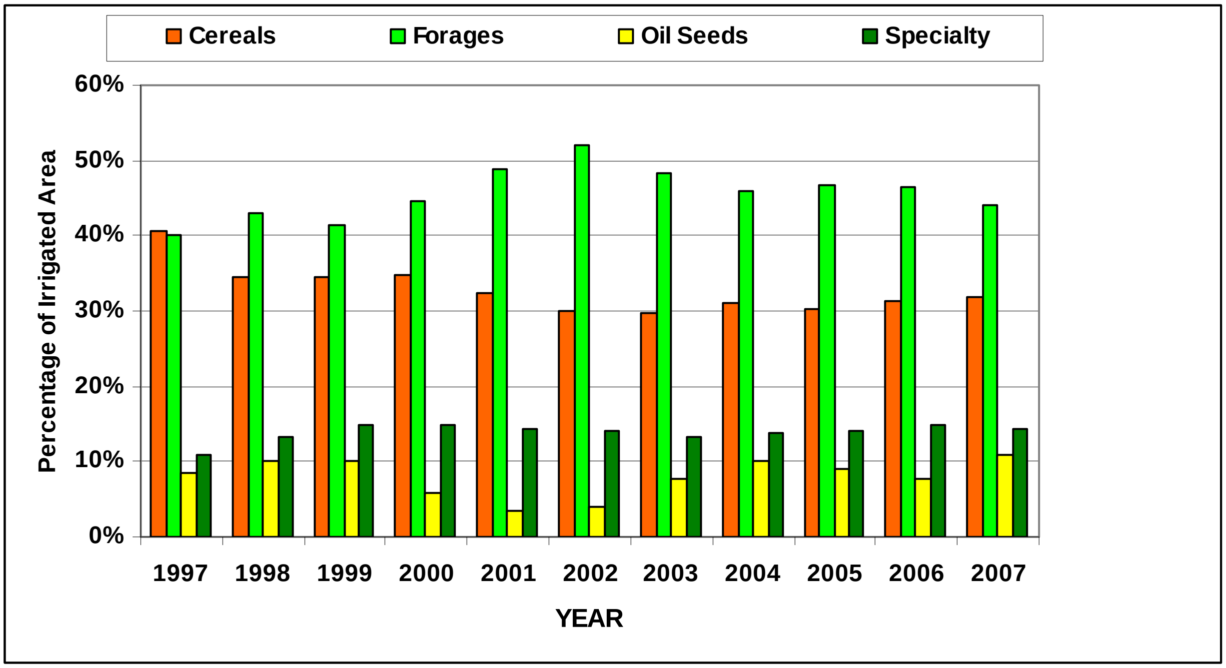

Figure 17: Trends in Crop Mix Shifts within Irrigation Districts 1997 – 2007

(Data Source: AARD – Annual Irrigation Information – 2007)

3.1.2 Projections for Future Efficiency Gains and Water Loss Reductions

NOTE: *It is important to recognize that in this and subsequent discussions, the expressions of quantifying water use improvements can easily be misapplied or misinterpreted. This is particularly true when using percentage formats to quantify changes. Due care needs to be taken to understand exactly what is being stated. For example, this report discusses both "changes in efficiencies" and "improvements in water use". They may both be expressed in percentage terms but are not the same consideration. A more complete explanation of these important distinguishing differences is offered in Appendix D and readers of the report are encouraged to review that material prior to continuing with the remaining discussions and attempting interpretations of some of the computational content.*

As indicated earlier, efficiency improvements at the farm level can have great effect in reducing irrigation demands for water. It has also been recognized that, in particular, the increasing use of higher-efficiency low pressure drop-tube centre pivot sprinklers has led the way, in recent years, in facilitating these efficiency gains. As of 2005, approximately 47 percent of the irrigated area within the irrigation districts uses low pressure centre pivot (LPCP) systems to apply water (AARD 2005). In order to achieve, at least in part, desired CEP gains, the irrigation district community has proposed that the proportion of coverage by these LPCP systems, or something equivalent, may need to increase to at least 71 percent. (See Section 4.3.3) Further, this group has suggested that, in striving for higher water use efficiencies, a process goal of realizing the development of at least 80 percent of the irrigation land base being irrigated through some form of higher water-use efficiency centre-pivot sprinkler irrigation should be a committed objective.

Table 3-1 presents a possible scenario of future development which may achieve this improvement goal, at least within the irrigation districts. Building on the data trends from 2005 and 2007, a shift in the proportion of on-farm systems has been projected for a scenario reflecting future conditions. The latter sees the proportion of centre pivot systems, in general, increasing by more than 14 percent (from 67.15% to 81.2%). This includes all types of centre pivot systems, the bulk of which would be expected to be low pressure drop-tube types to achieve the proposed 71 percent of overall irrigated area coverage. This projected shift in on-farm irrigation methodologies generates a 4.4 percent differential in overall on-farm water-use efficiency from 72.0 percent to 76.4 percent. This would have the net effect of reducing water demand at the stage of delivery to the farm by nearly 5.8 percent. Nonetheless, as indicated in the following discussions, the net overall effect of this component of efficiency gain, in percentage terms, relative to the overall gross irrigation diversion demand (GIDD), will be somewhat less because it is only one of the aggregating water consumption or loss components.

Table 3-1: A Limited Sample Illustrating the Efficiency Improvements that Accompany Shifts in the Proportion of On-farm System-types within the 13 Irrigation Districts

Type of System	2005		2007		Future	
	Hectares	Proportion	Hectares	Proportion	Hectares	Proportion
Centre Pivot	336,357	63.90%	349,956	67.15%	433,726	81.2%
Wheel-Move et al	115,428	21.93%	100,226	19.23%	67,851	12.7%
Gravity	74,592	14.17%	70,954	13.62%	32,509	6.1%
TOTALS	526,377	100.00%	521,136	100.00%	534,086	100.0%
Overall Efficiency	**72.0%**		**73.3%**		**76.4%**	

Table 3-2 summarizes the efficiency levels, by water-use component, across the 13 irrigation districts. These efficiency levels are also referenced to the gross irrigation diversion demand (GIDD) at the diversion point, to determine the proportion of that demand consumed through each component (%GIDD). The current (year 2005) on-farm efficiency value (i.e. 72.0%) needs to be converted to represent its true overall (net) efficiency with respect to the GIDD. In the case of the 2005 conditions, an on-farm efficiency of 72.0 percent equates to an overall net efficiency, with respect to the GIDD, of 79.3 percent, meaning a loss component equal to 20.7 percent (100% – 79.3%) of the GIDD. This same calculation principle is applied throughout Table 3-2 to illustrate the current net efficiency losses and derive the net improvement for each irrigation water use component after applying the forecast efficiency gains.

NOTE: The measure of overall efficiency is the ratio between the amount of water actually reaching the crop and available for consumptive use requirements relative to the overall amount of water diverted at the source. Therefore, in Table 3-2, the overall efficiency is represented by the percentage of the GIDD that is consumed as “crop use”, that being **53.3 percent** in 2005 and projected to be **62.7 percent** in the future.

The current long-term average gross irrigation diversion demand (1976 through 2007) is approximately 501 millimetres per unit of irrigated area. However, with the on-going efficiency improvements within the irrigation districts during that period, gains that have been demonstrated and quantified within this report, they would suggest that a more recent period should reflect a reduced average diversion amount. As is described further in Section 4.3.2 of this report, ten-year rolling-average diversions have been calculated for the period beginning in 1976 and ending in 2007. For the year 2005, the rolling-average diversion value is computed to be an equivalent depth of 441 millimetres per unit of irrigated area. In applying the "%GIDD" each component of net use or loss to that gross demand, Table 3-2 also presents the calculated equivalent depth (millimetres) per unit of irrigated area that equates to the "%GIDD". For example, out of the 441 millimetres of gross diversion that is the 2005 rolling-average value, 235 millimetres is what is attributable to crop use, with the remaining 206 millimetres representing the accrued lost or unused portions. The 235-millimetre component can be considered to be the *"net crop irrigation requirement"*; that is, the net amount of water that irrigation needs to contribute, beyond normal effective precipitation, in order to satisfy the full amount of crop evapotranspiration.

Table 3-2: Summary of Projected Overall Water Savings, Across all Irrigation Districts, following Improvements in On-farm and Distribution System Components and In District Operations

Water Use Component	Current (2005*) Conditions			Future Projections			Potential Net GIDD Reduction
	Nominal Efficiency	Net Loss		Efficiency	Net Loss		
		%GIDD	mm		%GIDD	mm	
Crop Use	100.0%	53.3%	235	100.0%	62.7%	235	nil
On-Farm	72.0%	20.7%	91	76.4%	19.4%	73	4.2%
Conveyance	97.0%	3.0%	13	97.6%	2.4%	9	1.0%
Reservoir	96.5%	3.5%	15	96.1%	4.1%	15	nil
Return Flow	80.5%	19.5%	86	88.7%	11.5%	43	9.8%
NET GIDD TOTALS		**100.0%**	**441**		**100.0%**	**375**	**15.0%**

***** *The water-use component values indicated for "2005 Conditions" do not represent actual values for 2005 but are computed values based on the known proportional water use for each respective component and applied to the ten-year rolling-average GIDD concept that derived the 441 mm.*

Table 3-2, in a similar fashion, also provides an indication of what the irrigation sector could achieve in efficiency improvements, projected through the next 10 to 15 years. If the current trends in irrigation systems upgrading continue through that period of time, substantial water savings could still be realized. In this summary and projection, on-farm water use efficiencies are forecast to improve from the current 72.0 percent (year 2005) to 76.4 percent, 10 to 15 years into the future. The 4.4 percent shift projected in on-farm application efficiency translates into a 4.2 percent reduction (improvement) in overall water use or gross diversion demand. This computational procedure is applied to the remaining use or loss components listed in Table 3-2.

Of the 7,631 kilometres of current conveyance works, 38.5 percent are represented by pipelines (see Table 2-7). It is estimated that approximately 70 percent of the open channel conveyance works still needing rehabilitation could be replaced with pipelines, which would eliminate associated seepage and evaporation losses, and potentially curtail some return flow losses. Using pipelines to rehabilitate 70 percent of the remaining 2,400 km of un-rehabilitated canals and lining any of the other un-rehabilitated large canals will only net a savings of approximately one percent of the gross irrigation diversion demand, with respect to seepage and evaporation losses. However, many of these replacement pipelines can operate as closed systems which could eliminate (or nearly eliminate) much of the return flow previously encountered, thereby lowering diversion demands and increasing overall efficiency. When all components and projected improvements are considered, the projected net gain is an increase in overall water-use efficiency of 9.4

percent (53.3% to 62.7%) and an improvement in water use noted by a reduction of 15.0 percent in the average GIDD (return flow included) or 5.2 percent (return flow not included as a loss component).

It should be noted that in applying the 10-year rolling-average value for 2005, the computed average crop water use actually refers to only that portion of the seasonal crop water requirement satisfied through irrigation operations. A 10-year rolling average of precipitation amounts would need to be added to the 235-millimetre value to derive the overall crop water use. As can be detected in Figure 16, the 10-year period ending in 2005 reflects the two years (2002 and 2005) with the highest amounts of seasonal precipitation recorded since 1976. However, this same 10-year period also contains two years (2000 and 2001) that imposed some of the highest crop water requirements in recent history. The combined effect of these extreme conditions and the frequency of occurrence of them within periodic (e.g. 10-year) cycles is a subject that may require more detailed analyses, but is beyond the scope of this report.

However, as the 235-millimetre amount across all districts for all crops for that 2005 year does appear to be somewhat low, relative to longer term averages, some caution in applying the net values in Table 3-2 could be in order. For example, in the future, if the "crop use" value increases, resulting from cropping pattern shifts to higher water use commodities, or irrigators increase levels of irrigation to optimize crop yields, or if climate change imposes higher net irrigation requirements, the overall gross irrigation diversion demand will increase. In that situation, if efficiency gains are made at the levels projected in Table 3-2, the overall net improvement may be equivalent, in percentage terms, but the GIDD will be greater. As an example, if future crop water requirements increase by five percent, the total GIDD would increase to almost 395 millimetres. Therefore, in projecting targets to strive toward for the future, a slightly more conservative value of 385 millimetres may be more realistic for irrigation districts to consider. For most of the private irrigation projects, where conveyance, storage and return flow components are almost a null factor, a rolling-average target of approximately 320 millimetres is suggested.

Despite what may appear to be small percentages of improvements, significant amounts of water are saved for every one percent gain in overall water use efficiency. Referring to the ten-year rolling-average equivalent GIDD for 2005 of 441 millimetres per unit of irrigated area (see Table 3-2), the equivalent overall average water use efficiency for 2005 is 53.3 percent. For every one percent gain in accrued efficiency, through improved on-farm, conveyance and return flow operations, up to the projected 62.7 percent, there will be an average net improvement in water use, or reduction in GIDD, of approximately 1.8 percent or 7.3 millimetres of water per unit of irrigated area. Across 500,000 hectares of irrigated land, each one percent efficiency gain could translate into approximately 36.5 million cubic metres of water being made available for potential use, directed either within the irrigation sector or to other uses. This is equivalent to a flow of approximately 2.8 cubic metres per second running continuously through the five-month (153-day) irrigation operating season.

3.1.3 Forecasting Methodology – Computer Modelling

In recent years, the evolution of computer modelling has resulted in the development of excellent tools for the analyses of a variety of potential future scenarios. The ability to adjust any number of the influencing variables allows for countless sensitivity analyses of the effects and impacts on future conditions.

"*The Year 2000 Study*"[5] (IWMSC 2002) enabled the development of a unique and sophisticated computer model known as the Irrigation Demand Model (IDM). For any given situation of distribution configuration, on-farm irrigation system mix, crop mix, weather conditions, management level, and the like, the model produces a historical summary of predicted irrigation demand over a selected period of time. (More details on the functionality and use of this model can be found in Volumes 1 and 4 of the reports from "*The Year 2000 Study*".)

Figure 18 illustrates a graphical representation of the results of an IDM run. It represents the irrigation area, water supply infrastructure and on-farm irrigation conditions prevailing in 1999 but subjected to the climate conditions as they have been detailed for each of the years from 1928 through 2001 (AARD 2004). The gross irrigation diversion demand is the modelled requirement of irrigation system water accruing all the way up to the source diversion point (i.e. includes crop water requirements plus application, conveyance and storage losses, plus return flow). As can be seen, the irrigation demand can be extremely variable from one year to the next. The average gross demand at the diversion point, through the 74 years of varying climate conditions, is 392 millimetres per unit of irrigated area, ranging between 131 and 578 millimetres. The gross irrigation diversion demand is always within the licensed allocation amount, other than for the exceptional years of 2000 and 2001.

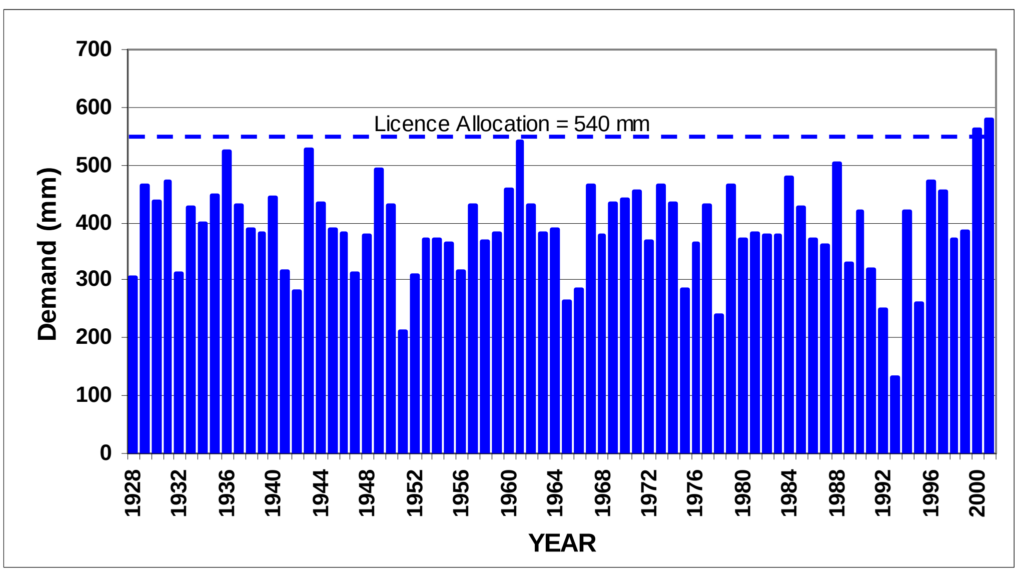

Figure 18: A Typical IDM Output of Historical Gross Irrigation Diversion Demand. (Data Source: AARD)

The IDM has been used by AARD to analyze numerous irrigation scenarios, for individual irrigation districts, private irrigation blocks and for irrigation districts as a whole. A very limited number of IDM results are listed in Table 3-3 to provide a summary of the sensitivity of potential irrigation adjustments on future diversions.

[5] "*The Year 2000 Study*" is the common name that is conventionally used to reference the study reported through the "*South Saskatchewan River Basin – Irrigation in the 21st Century*" report.

All relative change percentages are compared to the base case (i.e. 2007 area conditions but 1999 actual farm and distribution system characteristics). The modelling results provide some indication of the effect of any one adjustment, compared with the base case. Where two or more changes occur simultaneously, the resulting variation is additive. For example, if irrigation producers do make the crop shifts predicted and continue to upgrade their on-farm systems, but then irrigate to a near optimum irrigation management level, the net result could be a 6.9 percent increase in irrigation water demand (i.e. +3.1% - 5.7% + 9.5% = 6.9%).

Table 3-3: Summary of IDM modelling analyses for variable scenario configurations

Scenario Variable	Irrigated Area (ha)	Expansion Proportion	Gross Diversion (m^3 x 1000)	Change in Gross Diversion
Current (2007) Irrigated Area	490,400	n/a	2,187,018	**n/a**
Irrigated Area Expansion - Case 1	535,400	9.18%	2,305,681	**5.4%**
Irrigated Area Expansion - Case 2	588,940	20.09%	2,479,483	**13.4%**
Irrigated Area Expansion - Case 3	642,480	31.01%	2,623,666	**20.0%**
Shift in Crop Mix to More Forages and Specialty Crops				**3.1%**
Shift in On-Farm Systems to Higher Efficiency Applications				**-5.7%**
On-Farm System Management Efficiency Improvements				**-3.0%**
Increase in Crop Water Management to Near Optimum				**9.5%**
Improvements in District Return Flow Management				**-3.3%**

3.1.4 Climate Change Effects

Global warming, its effect on climate change and the resulting impact on many facets of natural earth functions have received considerable attention in recent years. Yet, the related science, in many ways, is still in its infancy. When it comes to analyzing the impact of climate change on irrigation demand, there has been very little research undertaken that provides much in the way of confident prediction, particularly in Alberta. The exception, to some degree, is the work carried out in 2005 and 2006 by AARD. A more thorough discussion of this work is provided in Appendix C.

Various Global Circulation (computer) Models (GCMs) have been developed during the past ten years or so to assist in the forecasting of climate conditions arising from the influences of predicted global warming. Those climate predictions have been adapted by AARD to create a variety of climate data files reflecting changing climate scenarios. By applying those climate files to IDM computer modelling runs, some quantitative sense of changes in irrigation demand have been generated by comparing the climate change files with the current climate condition reference files.

GCM data is applicable at a broad regional scale, at best. Therefore, in examining climate change modelling results, the accuracy of the output values is less important than recognizing trends and orders-of-magnitude in variations. In general, it was found that the average growing season precipitation decreased by approximately 7 millimetres, while the average annual precipitation increased by approximately 20 millimetres. Coupled, with slightly less growing season rainfall were somewhat higher temperatures, resulting in an increase in evapotranspiration amounts. The overall impact resulted in a net increase in gross irrigation diversion demand of about 13 millimetres per unit of irrigated area. This compares with the efficiency-gain comparator (Section 3.1.2) that suggests that for every one percent in efficiency gain, the equivalent of approximately 7.3 millimetres of water, per unit of irrigated area, could be saved. In other words, where a 1.8 percent increase in efficiency is achieved, there could be an extra 13.8 millimetres

(1.8 x 7.3 mm) or so of water applied to the land without increasing the overall gross diversion, possibly mitigating some of the projected effects of climate change.

3.2 Irrigation Water Supply Forecasting

The supply of water to the irrigation sector is directly related to the volume and timing of flow in the rivers and the amount of water stored in reservoirs. Only a portion of the river flow is available for irrigation use. In high runoff periods, river diversions and on-stream storage reservoirs may not have the capacity to divert or contain all the flow. In other times, flow must be augmented in the rivers to support instream needs and meet the commitments to other downstream users.

Natural river flows can be extremely variable from season-to-season and from year-to year. Figure 19 illustrates, as one example, the variability in natural flows within three tributary rivers above the Oldman Reservoir in the SSRB, namely the Crowsnest, Castle and Oldman Rivers. Substantial variances from the mean (as represented by the red line in Figure 19) are typical for river systems in the SSRB. In some years, the volume of the natural runoff is less than the gross irrigation diversion demand and the main benefit of southern Alberta's reservoirs is put to use in buffering water supply shortfalls. On-stream reservoirs can directly supplement river flows for downstream users and the environment. However, off-stream reservoirs

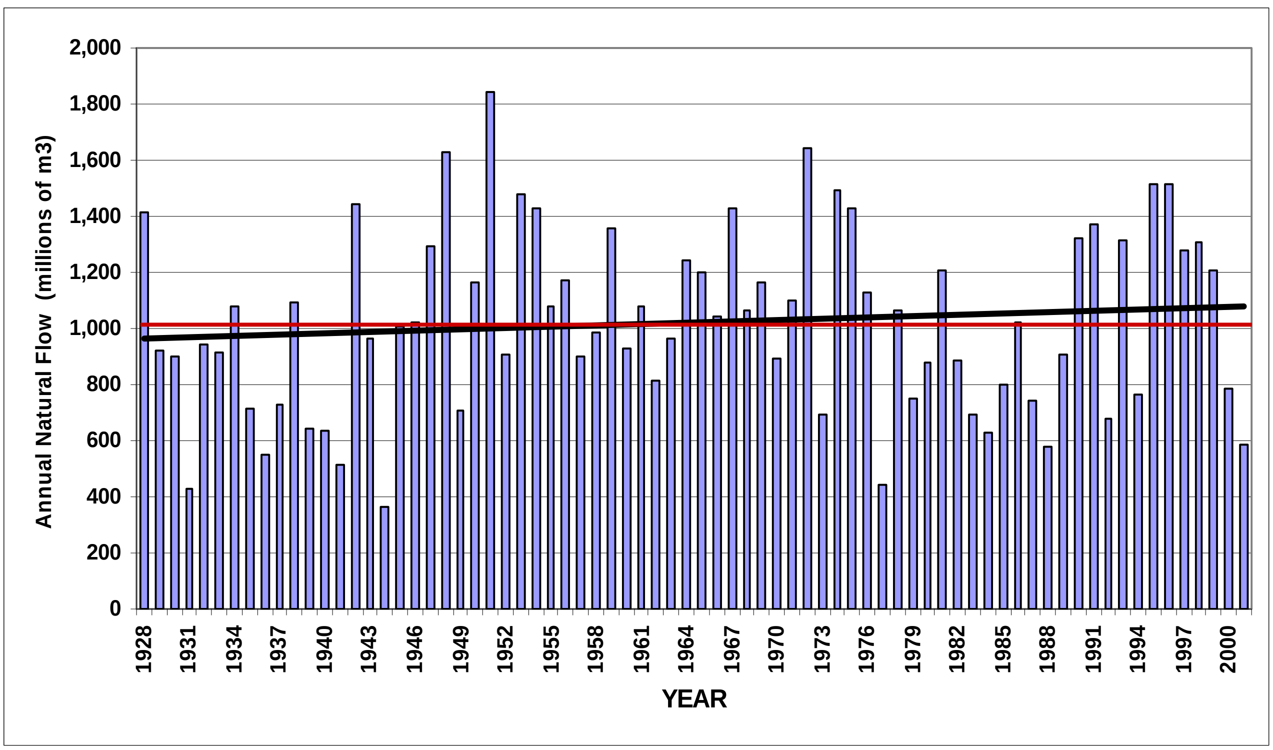

Figure 19: Historic natural flows of the Oldman River above the Oldman Reservoir, where the mean annual flow is indicated by the red line and the flow trend is represented by the black line. (Data Source: AENV)

can also serve the same purpose in a less obvious manner. Where river diversions have to be restricted, supplies within off-stream reservoirs can supplement the water available to irrigation districts and reduce demands on the rivers during critical low-flow periods.

On average, the irrigation sector diverts approximately 66.4 percent of its licensed allocations each year. This means that a substantial flow of allocated water is still available to benefit other users, the river environment or as an enhanced water supply flowing into downstream jurisdictions such as the province of Saskatchewan.

The irrigation sector is licensed to divert 43 percent of the natural flow of the SSRB and MRB, currently returning approximately 20 percent of that amount (or consuming 80 percent of what is actually diverted). Considering that the irrigation sector does not divert or consume its full allocation, an average of about 77 percent of the natural flow remains available in the river system for other uses.
(Net consumptive use = 43% x 66.4% x 80% = 22.8%.)

3.2.1 Forecasting Methodology – Trend Analyses

Evaluations of trends in river flow regimes have created much conjecture and opposing views. Figure 19 also illustrates the projected trend (black line) for the combined river flows at that point in the Oldman River watershed. As can be seen, the trend projections reveal a slightly increasing natural flow. Conversely, a similar analysis of natural flows of the Oldman River (per AENV data) at Lethbridge indicates a very slight decline in the 74 year trend line. Similar analyses of other SSRB rivers are also inconclusive or may suggest trends of declining flows (Rood et al 2005 & 2008). Although it is recognized that certain contributors such as glacial melt-water may be changing, a logical conclusion, at the present time, until more conclusive determinations can be achieved, is that annual river flows will continue at historical variable levels with the caution added that there could be the possibility of some measureable decrease through the next 50 years.

3.2.2 SSRB Operational Simulations Methodology – Computer Modelling

As with the analysis of irrigation demand, computer modelling has been utilized with respect to characterizing watershed flow regimes and basin operations. For the SSRB, the most widely used modeling tool that has been developed and applied by AENV is the Water Resources Management Model (WRMM). It is used for water resources planning and was an integral component in the analyses carried out by the “Year 2000 Study” project. The WRMM applies the historic flows of the SSRB, the operations of the water management infrastructure and legal priorities as defined by water licences to simulate basin operations.

When integrated with the demand output from the IDM, the WRMM provides output that indicates when gross irrigation diversion demands can and cannot be satisfied, including a measurement of any predicted shortfall. Figure 20 reflects the irrigation demand histogram presented in Figure 18, except that Figure 20 also includes an indication of when water supply deficits occur and the magnitude of those deficits, as computed by the WRMM. For this modelled scenario, the gross irrigation (or diversion) demand is measured at the top of the histogram bars. The red portion indicates the water supply deficit.

The net impact of those shortfalls depends on the magnitude and the frequency in which they occur. Consecutive shortfalls can be quite detrimental if storage reservoirs cannot be replenished prior to commencement of the second year's peak demand period.

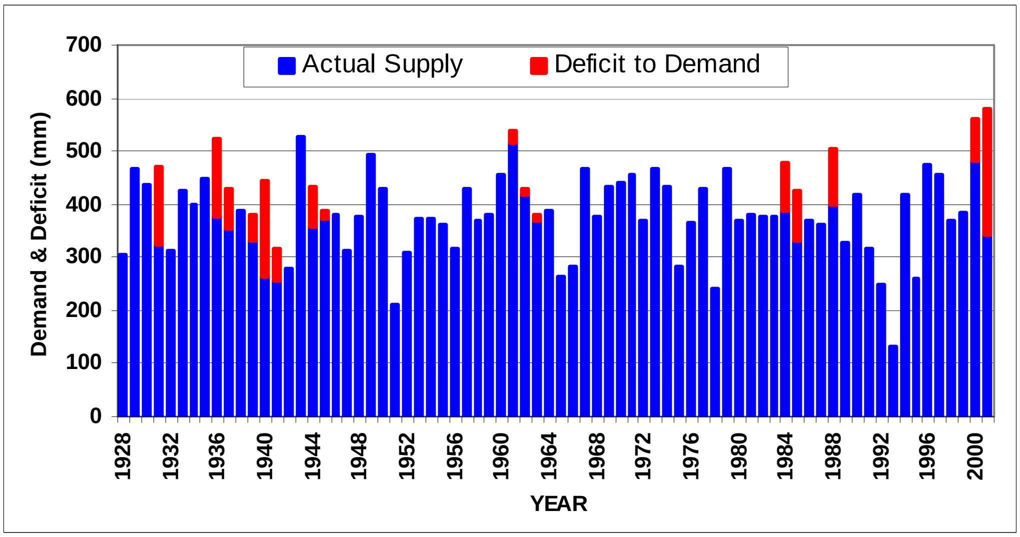

Figure 20: A Typical IDM Output of Historical Gross Irrigation Diversion Demand Combined with the Output of Water Supply and Deficits from the WRMM. (Data Source: AARD)

3.2.3 Climate Change Effects

Credible applied research is somewhat lacking on the question of potential global warming impacts on irrigation water demands, particularly for Alberta conditions. Scientific information is even more lacking when it comes to making projections on future watershed hydrological conditions under climate change scenarios.

Currently, as far as the SSRB is concerned, the best information on this subject was recently published in the report, "*Climate Change and Water – SSRB Final Technical Report*" (Martz et al 2007). Within that study, the National Water Research Institute of Environment Canada modelled several different climate change scenarios and analyzed the results relative to their impacts on future flow volumes in the three major river basins of the SSRB. As may be expected, there was no definitive answer but a range of possibilities. These projections are summarized in Figure 21.

From these modelled predictions, it was determined that the SSRB annual flows could decline by as much as 16 percent or increase by as much as five percent. The projection using the overall average indicates a reduction in total annual flow volumes of approximately eight percent.

The other significant consideration in examining the potential effects of climate change is the potential shift in precipitation and runoff patterns. It has been predicted that precipitation events may become more infrequent but greater in severity. Similarly, winter snowfall accumulations may be less and winter rain more prevalent due to a warming trend. This could lead to a change in the shape and timing of the annual runoff hydrographs for the SSRB streams and put into question the effectiveness of current operating procedures and the capabilities of existing diversions and storage facilities to capture an adequate water supply for later use.

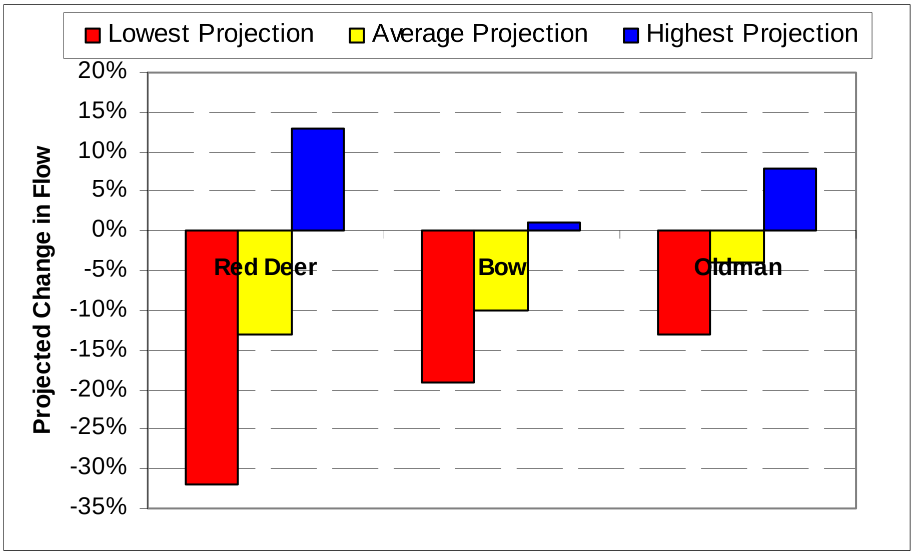

Figure 21: Projected Shifts in River Basin Annual Outflows Resulting from Climate Change Projections

3.2.4 Contribution of On-Stream and Off-Stream Storage

One of the most critical watersheds from an irrigation perspective is that portion of the Oldman River Basin that is referred to as the "Southern Tributaries", which includes the drainage basins of the Waterton, Belly and St. Mary Rivers. It supplies water to 38 percent of the irrigation area within the SSRB and more than 70 percent of the irrigation area within the Oldman Basin. Figure 22 provides a comprehensive picture of the relationship between the net annual flow volumes of the Southern Tributaries, the annual irrigation demands and the resulting deficits. (Net annual volume refers to the balance of water available after the minimum instream flow requirements are satisfied.)

The blue line in Figure 22 represents the average annual net watershed outflow volume, which is considerably lower than the dashed green line representing the approximate total volume of water licensed for irrigation withdrawals. The top of each blue bar represents the natural water supply in each year, while the green bar indicates the gross diversion demand (GIDD) for each respective year. In those years where the GIDD value exceeds the natural supply (i.e. 1988, 1992, 2000, 2001 and 2003) an apparent deficit occurs, as indicated by the red bars. The apparent supply shortfalls for those five deficit years vary between approximately seven and 40 percent of the GIDD. As an example, in 1987, the natural supply was 915 million cubic metres, while the GIDD was only 785 million cubic metres. Consequently there is no deficit indicated. In 1988, the GIDD was just over one billion cubic metres, whereas the natural supply satisfied only 690 million cubic metres of the GIDD. The result was an apparent deficit of approximately 320 million cubic metres.

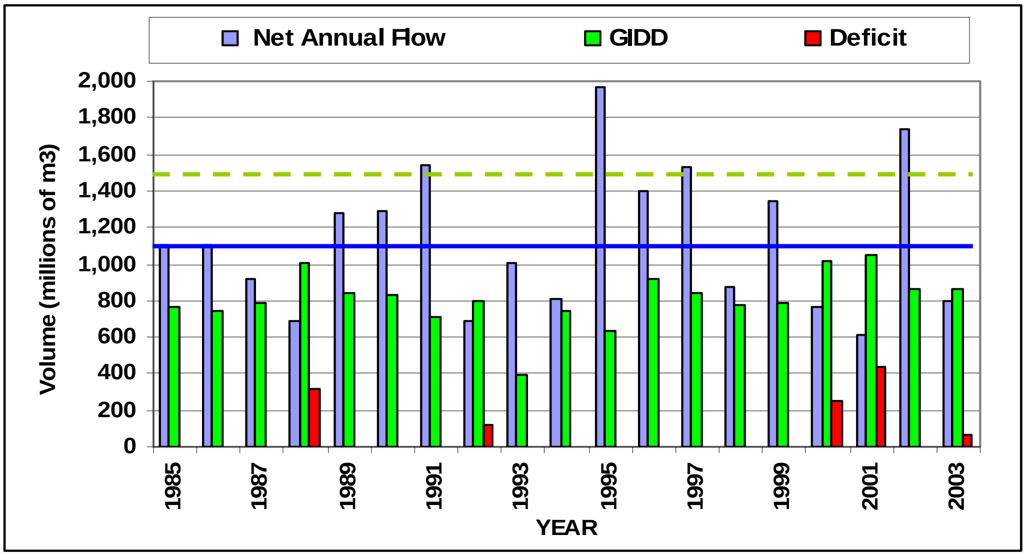

Figure 22: An Illustration of the Variability in Water Supply, Irrigation Demand and the Buffering Effects of Reservoir Storage in Mitigating Deficits Associated with the "Southern Tributaries" Watershed

However, the only year in which affected irrigators did actually experience a real impacting deficit in water availability was in 2001. In the other years of apparent supply deficit, there were actually sufficient amounts of water available, drawing from the carry-over volumes of water stored in various reservoirs from previous years' accumulations. For 2001, reservoirs had been drawn down due to high water demands during the previous year's drought, compounded by the necessary lowering of the St. Mary Reservoir for critical maintenance purposes, and so could not recover due to the very low runoff conditions in 2001.

Table 3-4 summarizes the volume of storage capacity within the water supply reservoirs associated with the Southern Tributaries. The total volume of storage in this system is more than one-third of the total storage capacity within all water supply facilities in the SSRB. The buffering effect of water storage reservoirs can benefit both irrigators and the aquatic environment. Water can be retained during times of high flow, for later release during times of low flows to supply water users and help to achieve instream flow objectives.

Table 3-4: Summary of Storage Capacity Supporting Irrigation and Other Water Users Dependent on the "Southern Tribs." as the Source of Water

Reservoir Owner	Live Volume of Storage (millions of m^3)	
	Off-Stream	On-Stream
Irrigation Districts	428	nil
AENV Headworks	155	481
Sub-Total	**583**	**481**
OVERALL TOTAL	**1,064**	

3.3 Overall Projections and Impacts

In consideration of the foregoing and for the purposes of the Irrigation Sector CEP Plan, there is a reasonable expectation, through the next 10 to 15 years, that overall gains in water use efficiency will continue within the irrigation sector. For example, for every five percentage points of upward efficiency change from the 2005 levels, there could be almost a nine percent reduction in gross diversion (conservation gain). A similar reduction could possibly be achieved on a per unit of irrigated area basis. However, if the water saved through efficiency gains were fully used to accommodate effective and balanced expansion of the irrigation area, then the net result would be little change in the volume of water diverted, meaning there would be no conservation gain but rather an efficiency gain that translates into a productivity gain.

On the other hand, should unit area irrigation demands increase due to climate change effects, or should the available water supply be reduced for some reason, the result may be that any potential gains in water savings may be needed to maintain the current irrigated acreage at the current level of risk. Should this be the case, other options should likely be considered by the irrigation sector, sooner rather than later, strategies that involve new and innovative methods with respect to risk management strategies.

4. Overview of Opportunities for CEP

4.1 Identification of CEP Opportunities

The irrigation sector has dramatically improved its water use efficiency during the past three decades. This has occurred primarily as a result of the individual initiatives on the part of irrigation producers and partly through the re-development of substantial proportions of irrigation district conveyance and drainage infrastructure. Other technological advances in water management and operational policies have, to a lesser extent, also made contributions to efficiency gains or water savings. However, it is recognized that operational policies may become greater factors in the future as the potential for water savings resulting from technological upgrades becomes more limited.

The irrigation sector has demonstrated its commitment to working toward ongoing improvements in water use efficiency and productivity. Although Alberta's *Water for Life* strategy does, on one hand, have an expectation of a conservation of water, partly to the benefit of aquatic ecosystems, the 30-percent improvement goal is focussed on *efficiency* and *productivity*, which does not necessarily demand that less water be used, as it would if the goal was solely water conservation. These two differing concepts continue to be a source of some confusion and misunderstandings for Albertans. The irrigation community does, however, understand that the very senior water allocations held by the sector are to be used wisely and effectively, as much as possible, to the benefit of all stakeholders.

The irrigation sector is also committed to ensure that where its allocation of water can be conserved to provide other social, economic and environmental benefits, it will continue to strive to facilitate those needs as well.

4.1.1 A Process of CEP Opportunities Identification

To facilitate stakeholder input to identifying CEP opportunities, the Irrigation Sector CEP Project Team (steering committee) convened a one-day workshop for interactive discussion and solution identification. Forty-six (46) individuals, representing a variety of interests and range of expertise in irrigation water use, was invited to contribute to the deliberations. These participants included irrigators, irrigation district administration and operations personnel and also representatives from municipalities, industry, other agricultural water users, government agencies and environmental organizations. (More detail on the process of the workshop can be found within Appendix I.)

An extensive list of CEP opportunities was derived by the workshop. Each participant then indicated which opportunities they thought had the greatest potential for achieving CEP gains. Overall, approximately 20 opportunities were identified. Not all items identified were included within the final list of stakeholder-preferred selections, but all are shown in Appendix I, where more detail is provided. The identified opportunities receiving the highest level of preference are discussed in more detail in Section 4.2.2.

The prioritization of the opportunities was a matter of the participants' individual perspective. They based their choices on what each saw as the preferred solutions to what they perceived as the real need.

4.1.2 Additional Opportunities Identification from Other Sources

In addition to the identification of CEP opportunities at the foregoing workshop, further review of conditions and associated recommendations arising from other jurisdictions was carried-out. These investigations were focused on those irrigated areas that are similar in nature to Alberta's irrigation sector and are also challenged with managing finite water resources, or are jurisdictions where comprehensive analyses of overall CEP opportunities are being undertaken.

Some of the related findings include:

- "Irrigation Systems for Idaho Agriculture"; Howard Neibling, University of Idaho.
- "The Water Information Program"; a newsletter series for southwest Colorado communities.
- "Colorado High Plains Irrigation Practices Guide"; Colorado Water Resources Research Institute
- "More with Less: Agricultural Water Conservation and Efficiency in California"; Pacific Institute of California
- "Water for Agriculture – LEPA"; Texas A & M University
- Water Management in the Murray Darling Basin of Australia
- "Analysis of Canadian and Other Water Conservation Practices and Initiatives"; Canadian Council of Ministers of the Environment (CCME).

These additional references contain some similar themes. Such concepts or opportunities as applying new technologies, innovative techniques, adopting rigorous conservation-minded policies, full-cost accounting and risk and reward systems were commonly referenced. In each of these categories, there are some worthy elaborations that the Alberta irrigation sector may want to examine further to advance its CEP gains. Some concepts may provide worthwhile options for exploration and venturing "outside the box". Further explanations of the findings from these external sources are summarized in Appendix J.

4.2 Analyses of Identified Opportunities

Efforts to make CEP gains will likely involve both demand-side management and supply-side initiatives. Demand management functions can include such concepts as adopting more efficient water application technologies, utilizing smart irrigation scheduling programs, reducing conveyance losses or limiting the need for water flow-through from the system, otherwise known as return flow. Supply-side management can involve the development of new or expanded water storage facilities, supplementary diversion sources or adjustments in the management protocols of reservoirs that favour meeting diversion demands from downstream users or the instream flow needs of affiliated river systems.

4.2.1 Applying Selection Criteria to Identified Opportunities

CEP opportunities may be solely a *Conservation, Efficiency,* or *Productivity* gain(s), or a combination thereof. Usually, where there is a gain in *Efficiency*, there is either a positive outcome in *Conservation* or in *Productivity*. For example, where water use becomes more efficient, the result can mean reduced diversions and a potential benefit to river flow. On the other hand, water savings accrued through *Efficiency* gains may be used to irrigate new areas of land such that diversions are not reduced and *Conservation* is traded for increased *Productivity*.

This report has attempted to demonstrate where and by how much the irrigation sector has, and could in the future, reduce the amount of water that is either consumed or lost by flowing unused through the systems. How these water savings are converted into other uses becomes a significant factor in how various CEP initiatives are measured against such things as benefits to the environment, social impacts and effects on other sectors. For example, if all the water saved is transferred into the irrigation of new lands, then source diversions would likely remain unchanged and river flows would not increase. Measurable productivity increases from those efficiency gains would be achieved. On the other hand, if return flow water volume was not reduced but re-directed to other uses such as wetland development, there may be no environmental gain to the instream flow at the river diversion but an environmental gain at the lower reaches of the system would be achieved.

4.2.2 Analyses of Selected Identified Opportunities

Although all of the identified opportunities in section 4.1.1 may have merit, the scope of this assignment dictates that only the top ranked six or seven concepts would be analyzed to any degree.

The following provides explanation on how some of these opportunities may influence change, to what degree a gain may be achieved and what costs may be incurred. Not all of the identified opportunities can be quantified within the scope of this reporting, but where possible, the respective opportunity is qualified. Much of what is being elaborated upon herein is more relevant to irrigation district operations as opposed to the private irrigation operation. The difference in the nature of the two and the larger impacts of the irrigation districts' incremental efficiency gains, endorses that most of the emphasis be focused on the irrigation districts and their operations.

1) *Expand or enhance on-stream and off-stream storage opportunities*: This is seen as a *Conservation* opportunity where water can be diverted during times of high river flow and stored for later use, allowing river diversions to be reduced during times of critically low flows to better protect the in-stream environment. However, reservoirs do suffer water loss from evaporation which must also be factored into a benefits analysis. In addition, proper assessments for any such proposed facilities would need to be carried-out to determine if there would be any net harm to the aquatic environment, particularly in already stressed river reaches.

   The benefit of retaining adequate storage within reservoirs was discussed in Section 3.2.4. The development of new or the enhancement of existing on-stream storage is recognized as a very efficient and cost-effective form of water storage, given that such facilities are usually able to both capture all run-off and to sustain instream flows in times of low run-off. The development of on-stream reservoirs is seen as being beyond the purview of the irrigation sector and would have to be pursued in another forum, perhaps in a watershed planning initiative.

Off-stream storages can be more readily developed through irrigation district initiatives and can reduce the risk of supply shortfalls. The direct benefits for irrigation use may not be as available as one might expect. The networks of diversions, conveyance canals and integrated reservoirs have their own unique water supply characteristics and must be assessed as an operational unit rather than simply looking at storage capacity alone. Nonetheless, off-stream reservoirs do provide opportunities for capturing return flows for reuse, increased recreational activities, fish and wildlife habitat, as well as adjoining wetland developments. The capture of return flows could be measured as an *Efficiency* gain and the other benefits can be reflected as *Productivity* gains.

A large internal off-stream irrigation district reservoir would have a capacity of approximately 60 million cubic metres and a minimum projected capital cost for such a facility would be $75 million (2008$). This amount of storage would increase the total irrigation district reservoir capacity by about five percent and could be expected to benefit irrigators as well as other sectors. As each reservoir development and operation is unique, it is difficult to accurately estimate the overall quantity of water-savings. It is assumed, for this exercise that, on average, the full reservoir capacity is turned over once per year.

2) *Enhance water control and monitoring systems within irrigation conveyance works*: This enhancement is seen as an aid to gains in water use *Efficiency* which would be confirmed through reductions in return flow. This could be manifested as reductions in diversion amounts or the water could be diverted to other uses, including the irrigation of new lands.

   Having the ability to better monitor water distribution through conveyance, drainage and reservoir works allows for better management. Automated responses would assist in ensuring the right amount of water is where it is needed, when it is needed. It is estimated that the incremental cost to properly monitor and automate the conveyance systems would, on average, add another four to six percent to the cost of re-developing those works. Given the current value of those works where control and monitoring systems would be most effective, it is estimated that the cost to install these systems would be in the order of $90 to $100 million.

   It has been projected by other irrigation water use agencies which have developed extensive automated monitoring and control systems that return flow volumes can be reduced by up to one-half.

3) *Provide improved access for producers to irrigation management tools and systems to support on-farm irrigation operations*: The implementation or enhancement of this concept would be expected to result in *Efficiency* gains. If irrigators are provided reliable and reasonably accurate guidance on when to irrigate and how much to apply, it has been shown that water use efficiencies can be increased by five to 15 percent and more nearly attain expected efficiency levels for the type of system being used.

   Irrigation management or irrigation scheduling has been a service offered by or through AARD for a few decades. For some specialty commodity growers, private firms have been contracted to provide such services or agents of commodity groups or processors have been trained to assist their growers with irrigation scheduling functions. Currently, the Irrigation Management Climate Information Network (IMCIN), developed and supported by AARD, provides irrigation producers with an on-line source to current and historical local and regional climate data that is required to manage irrigation scheduling functions. AARD also provides irrigation management software that utilizes such climate data in managing soil moisture levels and scheduling irrigations accordingly.

4) *Impose restricted allocations, by volume, to individual irrigation users*: This initiative would be intended as a *Conservation* opportunity that may be manifested through improved *Efficiency* in water use. This is a concept that has been in place and in use for quite some time in many outside jurisdictions and has been a practice of a few of Alberta's irrigation districts in recent years. Based on limited interviews by AARD with select irrigators, it may be concluded that restricting the supply of water to a specified amount can have a greater effect on encouraging an increased conservation ethic than does applying additional water supply charges. For private irrigators, their respective limits are defined within their individual water licences. Within irrigation districts, it is the district that manages the allocations to the irrigators.

   Establishing a water supply "cap" is a challenge. Where it is applied within Alberta irrigation districts, there is some variation in the individual policies applied, perhaps based upon to what degree there may be incentive to improve operations. Although one solution for all is likely not feasible or realistic, any constraints applied need to be restrictive, but fair enough so that greater conservation is achieved without affecting productivity.

   The application of this type of policy can be implemented at relatively low cost. A similar form of restricted water deliveries was imposed in 1988 and in 2001 in several of the southern irrigation districts in Alberta due to the extreme drought conditions. Mechanisms were developed to manage the water allocations and deliveries in an acceptable fashion, resulting in very high *Conservation* and *Efficiency* levels being achieved. The advantage of this type of system, versus a metering system on the farm, is that it implies greater accountability on the part of district irrigators for all the water that they order, not just what flows through their turnout delivery but also what flows past the delivery point as "ordered" but unused water (e.g. during system shut-downs). (This is further explained in Appendix G.)

5) *Develop and apply an innovative schedule of water use fees that charges individual irrigation users based on volume of use or overuse*: This concept would be an *Conservation* initiative, providing an encouragement for water users to be as diligent and efficient with their water use as possible or face monetary surcharges for over-use or misuse. Such monetary incentives are common in a variety of sectors and also within some other irrigation jurisdictions. The concept has been proven to be reasonably effective in deterring wasteful use of water. However, as has been mentioned previously, the vast majority of irrigation water users, who pump their water through their irrigation systems, already experience a use-related cost of diverting water or over-use deterrent; that being the cost of energy. This is an even greater reality for private irrigators who incur, on average, double the pumping costs of irrigators within irrigation districts due to associated higher pump lifts to get water to their fields.

   In considering such a proposal, there are a couple of aspects that need to be considered in determining the practical opportunity to implement such a management strategy. First is the real need to have very accurate ways of measuring actual water deliveries at individual farm turnouts. This is the same need as expressed with respect to restricting volumes of water delivered but likely would require a higher level of sophistication to acquire the accuracy that would be expected when dealing with monetary surcharges. To have some form of acceptable water meter installed at every irrigation delivery, district or private project alike, it is estimated that the total capital cost could be in the order of $25 million. However, unlike municipal water systems, the agricultural environment of sun, cold, dirt and rain can make it difficult to maintain typical metering systems, particularly with respect to operating functionality and accuracy. These factors and the unfiltered raw water quality are not always conducive to fostering instrumentation longevity. In order to hire qualified maintenance staff and provide applicable support resources, it is estimated that an additional $1.25 to $1.5 million would be needed for annual metering operation and maintenance.

Once again, as discussed in the preceding item 4, this type of monitoring system may not fully audit all of the water for which an irrigator is responsible.

6) *Development and/or greater utilization of more efficient on-farm water application systems*: This concept would be an *Efficiency* initiative and has been, through the past three decades or more, the largest single contributor to the notable efficiency gains accrued across the sector during that period of time. This is true at the on-farm level for both irrigation district and private irrigation operations. In particular, the greater predominance of higher-efficiency centre pivot systems within private irrigation projects has provided an even larger percentage to improved overall efficiencies where conveyance infrastructure is almost entirely non-existent or exists as closed systems yielding minimal consumptive losses and negligible return flows.

Figure 14 in Section 2.5.3 illustrates the substantial improvements, through time, of the gains in on-farm water application efficiency within the 13 irrigation districts. Table 3-2 and accompanying explanations illustrate the significance of on-farm consumptive losses in the overall scheme of irrigation water use. Even small incremental improvements within this component of water use provide a large return.

A recent report prepared for Agriculture and Agri-Food Canada (AAFC) entitled, "*Irrigation Efficiency Scoping Study*" (UMA/AECOM 2008) has projected on-farm irrigation conversions to higher efficiency systems through the next 10 to 15 years. During that time, this report projects that almost 110,000 hectares of existing irrigated land in Alberta would see some form of application system conversion to a somewhat more efficient methodology. This would also be tied to an accompanying capital expenditure requirement estimated at more than $135 million. The associated total water saved was estimated to be 75 million cubic metres. Therefore, the on-farm capital cost per thousand cubic metres of water saved was estimated to be approximately $1,800.

Technologies such as Low Energy Precision Application (LEPA) centre pivot configurations can offer application efficiencies not yet experienced in Alberta. Although the technology has been demonstrated by AARD in the past, the additional expense of such systems and the adjustment in current farming practices have met with resistance to adoption by current irrigators. However, with LEPA application efficiencies being achievable in the 90 to 95 percent range, it is a technology that the Alberta irrigation sector may want to consider.

In addition to the shift to more-efficient systems, there are also system adaptations that can assist in reducing water loss and notably increase efficiencies. For example, many irregular shaped, surface irrigation fields may not lend themselves to conversion to such methods as centre pivot sprinklers. However, with the addition of gated pipe systems that provide better water control, or the development of field cross ditches to reduce lengths of run, or the installation of tailwater pumping systems that return field run-off water back to re-use in the field, surface irrigation efficiencies can be increased dramatically. Tailwater pump-back also yields the benefit of reducing return flows and reducing the potential for fertilizer, herbicides and the like from being conveyed into return flow channels and other run-off receiving water courses.

Irrigation management strategies could also inject some incremental effect in reducing irrigation water demand. One such technique that has been explored in other irrigation-intensive areas is the concept of “deficit irrigation”. This technique requires that a crop be appropriately watered during specific growth and maturation stages that are critical to ensuring good yield results. This means that during other stages of crop development, the supplied water can be shorted without any detrimental plant stress. This could yield water savings of approximately 10 percent.

7) *Continue and increase Irrigation Rehabilitation Program (IRP) funding*: Seepage and evaporation losses from irrigation canals has been substantially reduced from what existed 40 years ago as a result of the significant amount of rehabilitation work that has been accomplished during that time. This has been and continues as an *Efficiency* initiative. With more than 60 percent of the works rehabilitated, many of the works in the worst condition and the greatest contributors to water losses have largely been redeveloped such that a much higher percentage of canal seepage has been eliminated (see Table 2-1).

However, only about half of the conveyance works that can be replaced with pipelines have been. There are still 2,300 kilometres of conveyance works that could be replaced by pipeline. This would have a significant impact in reducing return flow quantities. It would cost $635 million to install the estimated 2,300 kilometres of pipeline. Given the current level of rehabilitation funding, including IRP co-funding and irrigation district independent commitments, estimated to average approximately $50 million per year, this initiative would take considerable time to fully implement. Further, in order to complement the need for effective CEP planning, future additional capital funding could be more directly targeted at rehabilitations that can be demonstrated to have the greatest potentials for CEP gains.

Beyond the traditional conveyance replacements that have been common-place in the past, concepts such as internal balancing ponds, and return flow pump-backs, among others, may offer some opportunity for increased irrigation district water use efficiencies. This would likely produce noticeable reductions in return flow. Some districts have developed balancing ponds and more are being considered. Return flow pump-back has been contemplated in recent times, but none have been developed.

4.2.3 A Summary of Selected Identified Opportunities

In order to better compare the foregoing opportunities, Table 4-1 lists the seven identified opportunities and relates them to projected water savings and costs of implementation, where possible to estimate. The values are all estimates and are provided as orders of magnitude values for comparison only. Actual water savings and associated costs could vary significantly. It is also important to note that the costs specified in Table 4-1 are capital costs only. Where applicable, annual operating costs and depreciation periods are estimated, recognizing that any capital improvement beyond the current state of development will have to be replaced or upgraded at some point in time. For example, in situations where water use monitoring or measurement is required, certain types of associated equipment will be required. Its respective longevity and maintenance requirements are affected by the degree of sophistication and accuracy needs of those systems.

Table 4-1: Summary of the projected benefits and costs of selected CEP initiatives

CEP Initiative	Projected Improvement	Annual Water Use Reduction (m^3)	Capital Cost		Annual O & M Cost	Depreciation Period
			Total	Per 1,000 m^3		
Enhanced Reservoir Storage	3%	60 million	$75 million	$1,250	$150,000	100 years
Water Control & Monitoring	4%	95 million	$100 million	$1,050	$1,500,000	10 years
Irrigation Management	3%	80 million	$6 million	$80	$6 million	10 years
Restricted Deliveries	3%	80 million	$5 million	$65	$250,000	20 years
Water Use Surcharges	4%	100 million	$25 million	$250	$1,500,000	10 years
On-Farm System Enhancements	4%	95 million	$155 million	$1,630	$3,325,000	10 years
Water Conveyance Enhancements	9%	120 million	$635 million	$5,290	$5,000,000	50 years

1) Projections are order-of-magnitude and speculative estimates only, for comparison purposes.

2) Water use reductions are not necessarily cumulative as the outcomes from some initiatives are dependent on the existence of others.

3) Some projected improvements are primarily a result of return flow reductions and do not necessarily indicate consumptive loss reductions.

A cost-benefit analysis is only one instrument to be considered in finally selecting a CEP initiative to implement. The irrigation delivery and application systems are complex and diverse. One opportunity may be most applicable in one situation or irrigated region and irrelevant for others. Therefore, before any particular initiative is undertaken by any individual irrigation district, or group of districts for that matter, more thorough analyses of the costs and benefits should be undertaken.

4.2.4 Understanding the Benefits of Efficiency Gains and Diversion Reductions

The discussions and information generated in the previous report chapters and sections convey the potential efficiency gains and water savings in volume (i.e. cubic metres) or in depth of water per unit of irrigated area, or in percentage reductions in diversions, or percentage gains from improvements. The differing measures can lead to some confusion in terms of the real effect of CEP improvements. The following example better illustrates what may be gained from the projected savings as improvements take place.

As an example, if it is assumed that 100,000 hectares of irrigated land realize an improvement in overall irrigation efficiency from 53.3 percent to 58.5 percent, the resulting saving in water averages 39 million cubic metres (see Section 3.1.2 and Appendix D). This is made up of a combination of reductions in consumptive losses and in return flow volumes.

As a result of increased efficiency, the reduced demand for diversion means the average volume of water saved each year could alternatively be used for the following examples.

- Expansion of irrigation to 8,000 hectares of new land;
- Meeting the needs of 8 new sugar beet processing factories (e.g. Lantic/Rogers Sugar)
- Meeting the needs of 8 new potato processing factories (e.g. McCain Foods)
- Meeting the needs of 6 municipalities the size of the Town of Taber.
- The development of sixty – 30-hectare wetlands
- Doubling the minimum instream flows of both the St. Mary and Belly Rivers during at least four months of the five-month irrigation season.

If equivalent gains were realized, for example, across 500,000 hectares of irrigated land, the resulting savings and alternate opportunities could be approximately five times the quantities listed as examples above. As more and more areas realize further gains toward these projected levels of efficiency, so too could there be a greater extent of alternative uses of the saved water.

It is important to note, however, the importance of the foregoing opportunities with regard to water licensing. In order for any of these enhancements to actually be secured, it will mean that licensed allocations would need to be authorized. As any water saved by the irrigation sector, through higher efficiencies, is a portion of its licence allocations, the ability for this water to be re-allocated for alternate use by others will be contingent on the willingness of irrigation sector licence-holders to transfer identified portions of their licences for these other uses. It will also depend on AENV's determination of beneficial consequences to authorizing such transfers. Regardless of the intent or willingness of licensees to transfer water to other users, both the *Irrigation Districts Act* and the *Water Act* require some reasonable rationale be applied and agreed-to that demonstrates that the licensee will require less water in the future, a result, for example, of net efficiency gains. This is the same principle applied within the *Irrigation Districts Act* with respect to authorizing irrigation area expansion.

4.3 Selected CEP Opportunities and Targets

In selecting CEP opportunities, it is recommended that the irrigation sector, for this initial CEP plan implementation strategy, continue efforts in those traditional areas which have yielded respectable responses to date. The recommended outcomes and target values are discussed in the following sections.

4.3.1 Irrigation Diversions

In principle and in general, the proposed water-use outcomes for the irrigation sector, derived through increasing water-use efficiencies are:

A) That annual gross irrigation diversions will not increase, on a total volumetric basis, from historical diversions.
B) That annual gross irrigation diversions will continue to decrease, on a per unit of irrigated area basis, from historical diversions.

These outcomes are intended to reflect the sector's commitment to on-going water-use efficiency improvements. To define realistic, achievable and acceptable targets, the extent to which efficiency and conservation gains can be generated needs to be known. For example, trends and available technology seem to indicate that overall gains in water-use efficiency levels, somewhere between 0.5 and 0.7 percent per year, may be achievable, at least through the next 10 to 15 years. However, water use is so variable from year-to-year that it is difficult to reference a starting point from which true progress can be measured. One of the critical challenges for the irrigation sector is to define such a reference benchmark that is appropriate.

The *Water for Life* strategy states that conservation, efficiency and productivity measurements are to refer to conditions in 2005. Annual irrigation diversions can vary significantly, due to the temperature-driven crop water requirement and the amount of precipitation received during the growing season. Another variable that can affect annual diversions, to a lesser degree, is the variability that occurs from one year to the next in actual irrigated area. Although 2005 was the year with the highest number of hectares irrigated, it was also a very wet year which resulted in a relatively low level of diversion. Consequently, the specific amount of gross diversion for 2005,by itself, is not a realistic benchmark.

In order to nullify the effect that year-to-year variation in irrigated area can have on the analysis of the diversion volumes, a weighted-average diversion for each year of data analysis has been calculated. The historic diversion was computed as the depth per unit of irrigated area for each year analyzed. Then, using the 2005 irrigated area (496,184 ha) as the common reference area for each year, the actual unit area diversion values are applied to arrive at "adjusted annual diversion volumes" for each year. These values provide a more useful comparison in terms of the variability in diversions that would have occurred had there been a constant irrigated area. The results of this adjustment are illustrated in Figure 23. As can be seen, the adjusted downward trendline becomes steeper, clearly showing the significant historical trend in relative reductions in water use. With the adjusted values, the degree of annual variability becomes even more pronounced, with 2005 seen to be the year with the lowest gross diversion volume, compared on an equivalent basis.

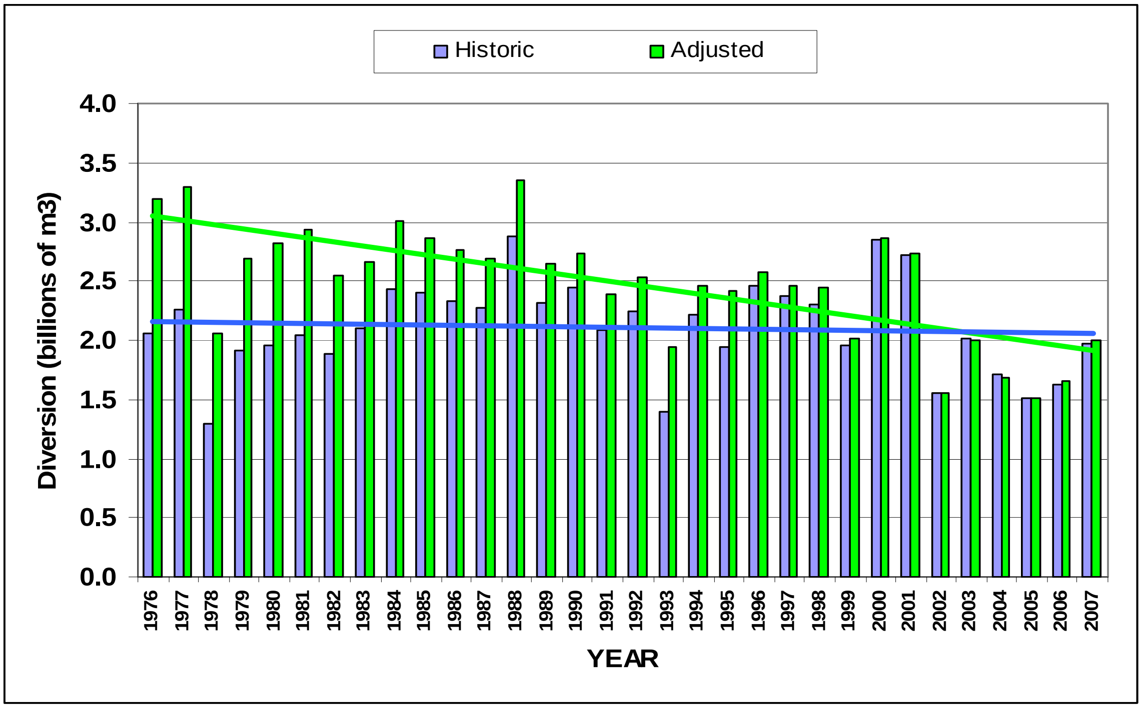

Figure 23: Comparison of "Historic" vs. "Adjusted Area" Diversions

In order to select a practical benchmark reference, it is necessary to minimize the year-to-year variability and examine longer-term average diversions. To accomplish that, rolling-average values for consecutive 10-year periods have been applied to the adjusted diversion values. The result is shown in Figure 24, including a noticeable downward trendline. The 2005 value nearly matches the trendline. In a similar fashion, the rolling-average diversion depth per unit of irrigated area for 2005 has been determined. As a result, the 2005 rolling-average adjusted-area value for diversion volume of 2.186 billion m^3 and the equivalent diversion depth of 441 mm/unit of irrigated area (2.186 billion m^3 over 496,184 ha) are proposed as the reference benchmarks from which to measure future CEP gains.

Based on the preceding discussion, it is recommended that, during the next 10 to 15 years, the irrigation sector commit to achieving:

a) 10-year rolling-average annual gross irrigation diversions that will not exceed the 2005 adjusted total volumetric value of 2.186 billion cubic metres.
b) 10-year rolling-average annual gross irrigation diversions that will continue to decline, on a depth per unit of irrigated area basis, from a reference point of 441 mm to 385 mm (see Table 3-2), unless uncontrollable factors such as climate change or substantive shifts to higher water-consuming and higher productivity crops make this extent of decrease prohibitive.

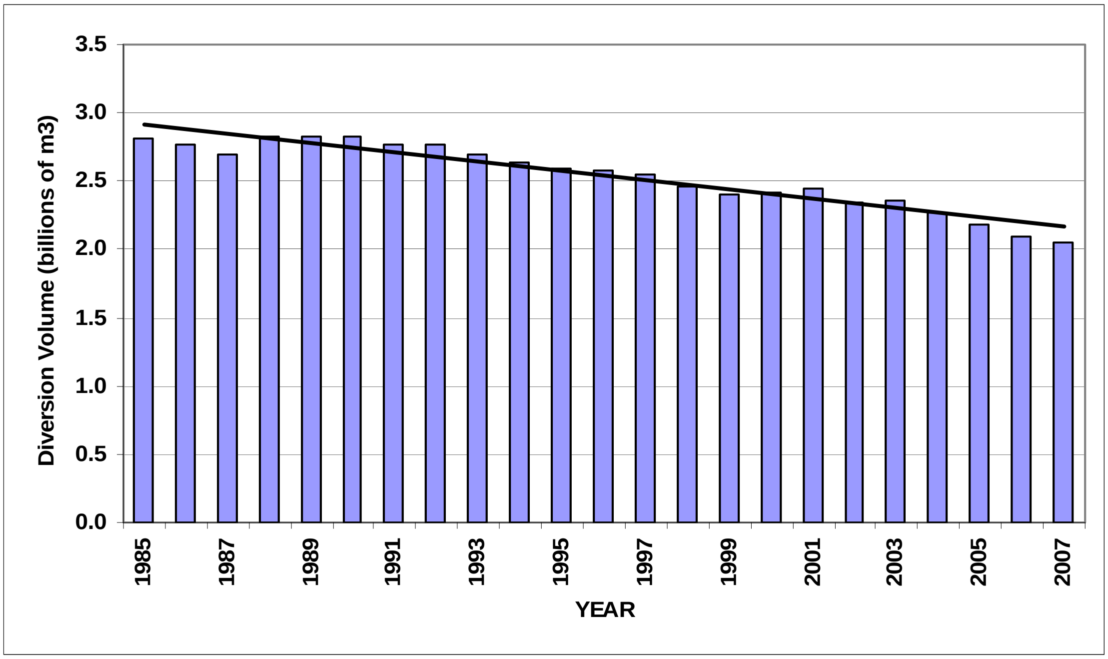

Figure 24: 10-year Rolling-average Diversion Volumes, Adjusted for the 2005 Irrigated Area

It is important to note, that the 2.186 billion cubic metres volume represents only about 63 percent of the total volume of all irrigation district licences. Therefore, in establishing these benchmark reference points and associated goals, it needs to be recognized that, in any given year, as such factors as weather and crop mix dictate, diversion volumes may exceed the target value, but remain within licensed allocations. However, on a 10-year rolling-average, the 2.186 billion cubic metres benchmark should not need to be exceeded and diversions measured according to the depth per unit area approach should decline from the 441 mm value. With respect to the latter, it needs to be emphasized, again, that as efficiencies reach a practical optimum level, the fundamental requirement to meet crop water requirements will tend to flatten the downward trendline.

In establishing these benchmark values for the irrigation districts, it was deemed advisable to consider their impact on potential future scenarios. Therefore, a series of years, with diversions similar to those recorded for 1995 through 2007, have been appended to the historical sequence of years (1976 to 2007) to project possible conditions to 2020. The values used are the adjusted diversions relative to the 2005 irrigated area, with that area assumed to remain constant, through to the year 2020. The 10-year rolling average values were computed for this extended period of time and the appended results are indicated in the graphing of Figure 25.

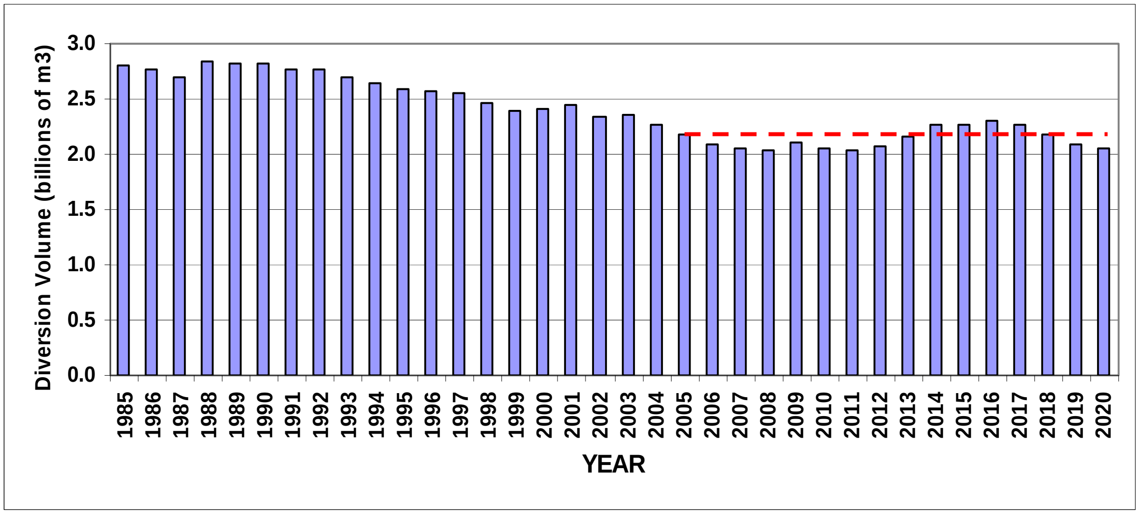

Figure 25: 10-year Rolling-average Diversion Volumes, Adjusted for 2005 Irrigated Area and Projected 13 years (2008-2020)

The average diversion demand from 2008 through 2020 is 2.147 billion cubic metres. However, the benchmark value of 2.186 billion cubic metres is seen to be exceeded in years such as 2014 through 2017. This would indicate that if irrigated area remains at the 2005 level and if weather conditions occur that create higher demands for water, there would be difficulty in achieving the desired diversion goal.

However, the irrigation sector is committing to on-going efficiency improvements, which means that these gains should be incorporated into the analyses as well. If it is assumed that there is an expected annual gain in efficiency of 0.5 percent per year, this would translate into accruing reductions in diversion volume averaging almost 0.9 percent per annum.

Alternatively, if the efficiency gains projected in Table 3-2 occur, it is anticipated that there could be a gain in efficiency each year that averages 0.7 percent through the 13-year projection. Annual incremental efficiency gains of that order would yield average water use reductions in the amount of almost 1.2 percent per annum. If the overall effect of these improvements, through the 13-year period, generates a reduction in gross irrigation diversion demand of up to 15 percent, it is a scenario worthy of consideration. Figure 26 presents a comparative consolidated graphing of these two efficiency-gain scenarios in comparison to the projected diversion demands shown in Figure 25, where no efficiency gains are imposed.

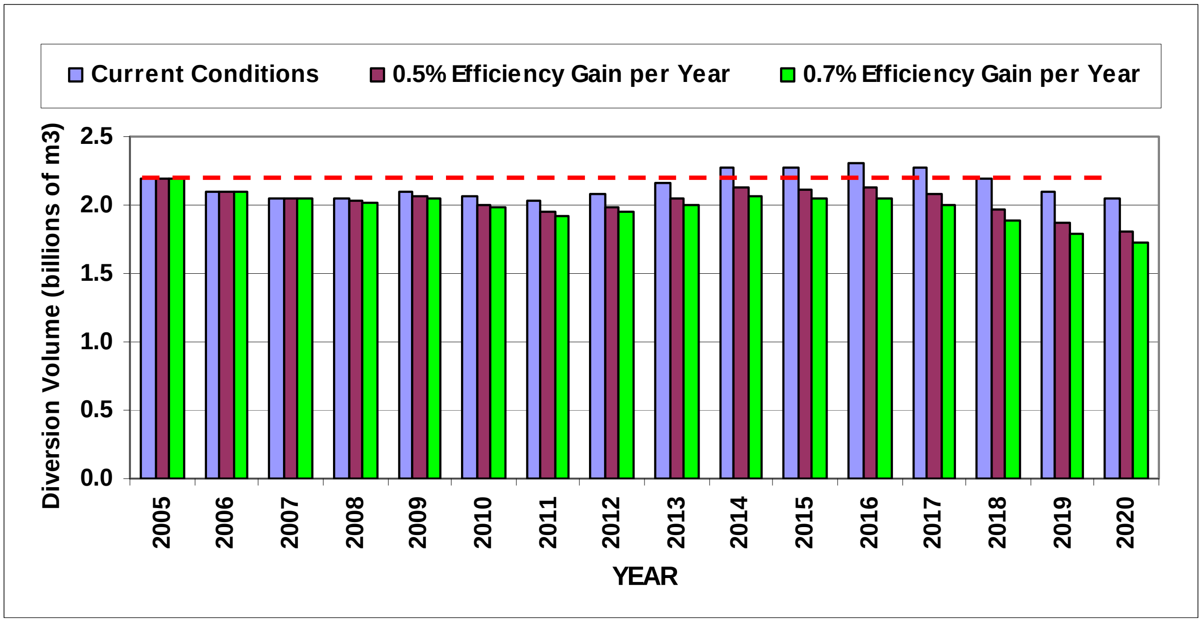

Figure 26: A Comparison of 10-year Rolling-average Diversion Volumes, Adjusted for 2005 Irrigated Area and Projected 13 years (2008-2020), for 2005 Conditions and Efficiency Gains of 0.5% and 0.7% per Annum

The results in Figure 26 indicate that the effects of generating either 0.5 percent or 0.7 percent efficiency gains each year mean that projected future rolling-average diversion volumes will be less than the recommended benchmark volume of 2.186 billion cubic metres.

However, the analysis needs to be extended further as there is an expectation, at least within a portion of the irrigation community, that as water is saved, a portion of it may be re-directed to expanding the irrigation base. This growth would be considered a productivity gain, as long as such growth occurs in accordance with efficiency gains and does not increase the risk of water shortages. Since 1976, the irrigation sector has experienced an average area growth rate of approximately 1.5 percent per year, with development tapering-off in the past few years to an average annual rate of less than 0.5 percent. Therefore, alternative sensitivity analysis scenarios have been developed where an assumed irrigation area expansion of 0.4 percent per annum is imposed on the 0.5 percent and 0.7 percent efficiency gain scenarios to determine what the combined effect of both efficiency improvements and irrigation growth may reveal. The irrigation area growth would equal the addition of approximately 30,000 hectares of new irrigation during the course of the next 13 years. The comparative results of the compound analyses are presented in Figure 27.

The results presented in Figure 27 indicate that with a combined effect of a 0.5 percent gain in overall irrigation district efficiency each year and simultaneous annual area expansion of 0.4 percent, there is an exceedence of the rolling-average benchmark value in year 2016 (2.199 billion m^3 vs. 2.186 billion m^3). If an efficiency gain of 0.7 percent per annum is applied, along with a simultaneous annual irrigation area expansion of 0.4 percent, then the highest future rolling-average diversion volume is derived for the year 2014 at 2.128 billion m^3 (vs. the target reference of 2.186 billion m^3).

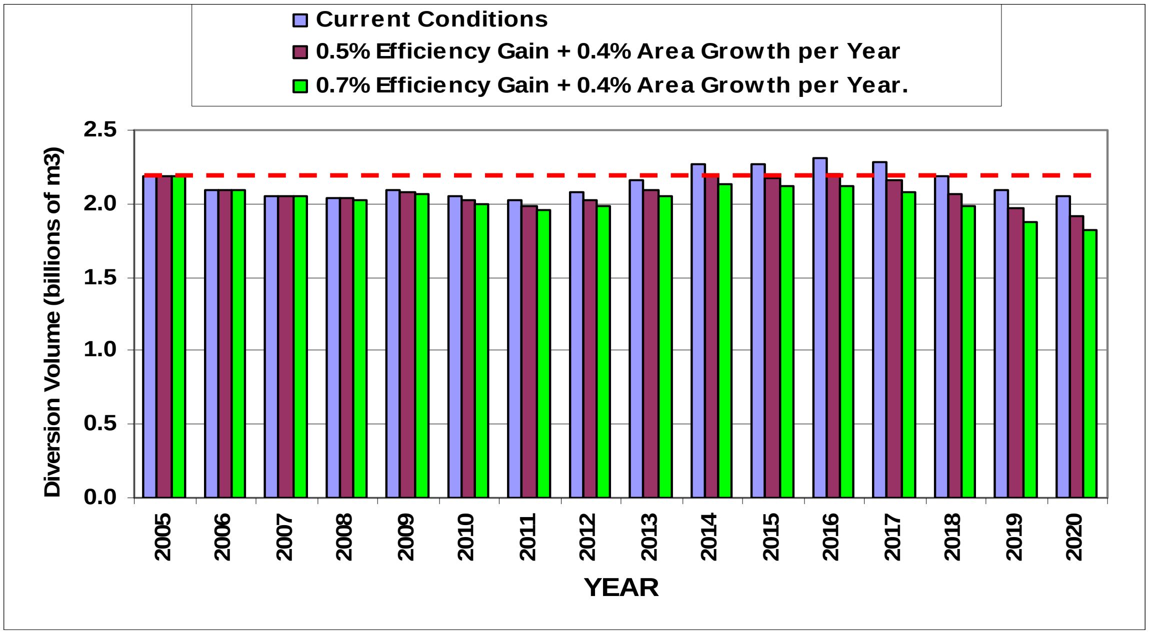

Figure 27: A comparison of 10-year rolling-average diversion volumes, adjusted for 2005 irrigated area and projected 13 years (2008-2020), for 2005 conditions and efficiency gains of 0.5% and 0.7% per annum, with a projected 0.4% area expansion per year

It also follows that as rolling-average diversion volumes decline and irrigated area remains constant or expands, the diversion depth per unit of irrigated area value will also decline from the reference benchmark of 441 millimetres.

It is likely reasonable to conclude that the applied rolling-average approach and the benchmark references are appropriate for tracking on-going water use performance. It is also likely appropriate to conclude that annual overall efficiency gains within the irrigation districts will need to average at least 0.5 percent if future computed rolling-average diversion volumes are not to exceed the target benchmarks. Further, if irrigation expansion is to occur, at an average rate of 0.4 percent per year, then overall efficiency gains averaging almost 0.7 percent per annum will need to occur simultaneously to support that expansion.

4.3.2 Reduced Return Flow

The desired outcome is that return flows would continue to decrease through the next 10 to 15 years, to a point where, on average, the overall return flow volume would be reduced to half of its current amount, on a per unit of irrigated area basis. This projection is reflected in Table 3-2. This is a potential target that could be reasonably achieved if capital is directed at the replacement of open channel canals with pipeline systems that re-direct unused water into existing or newly-constructed internal balancing ponds or reservoirs. Once again, depending upon on return flow volumes are perceived, these reductions could be seen as a conservation initiative or an efficiency opportunity or neither, depending either upon the downstream reliance on particular return flows or the net effect of how those reductions are re-directed. The addition of more comprehensive control and monitoring facilities will contribute to achieving this target as well. An emphasis on return flow monitoring will need to be rigorously applied in order to track real progress on return flow reductions.

4.3.3 Increased Use of More Efficient On-Farm Irrigation Systems

The desired outcome is that highly-efficient water-use irrigation systems will be utilized on 80 percent of the irrigated area. This is interpreted to mean that a low-pressure drop-tube centre pivot system, or something equivalent, is the benchmark system of reference, having a nominal efficiency rating of 80 percent. Therefore, any on-farm changes that see the conversion of lower efficiency systems to "80%-systems", of whatever type, would be seen as moves to the positive. The discussions around this concept, as summarized in Table 2-6 and in Table 3-1, provide overall projections for gains, from the 72.0-percent efficiency level in 2005 to 76.4 percent some 10 to 15 years in the future. Because of the diversity of on-farm system-types and the range of associated nominal efficiencies, a significant amount of system conversions will be required to achieve an "80-percent efficiency level on 80 percent of the irrigated area" condition. Determining the effect of this requires an analysis of changing the proportional efficiency contributions as methods shift. Even to achieve the projected 76.4-percent value, a composite mix of converted systems requires a proportion of low-pressure drop-tube centre pivots covering 71 percent of the irrigated area, a 50-percent increase from the 47.3 percent of the irrigated area that these types of systems covered in 2005. A significant shift from where the sector is today will only produce a few percentage points of efficiency gain. However, as demonstrated earlier, each percentage point of gain can mean a considerable volume of water being saved.

4.3.4 Increased Social, Economic and Environmental Outcomes

The development and operations of irrigation in Alberta has fostered considerable societal and economic development in a semi-arid area that had originally shown little potential. Through irrigated agriculture production, countless secondary and tertiary benefits have been created. Such things as conveying water to over 50 municipalities for domestic, recreational and habitat purposes or facilitating the operations of a diversity of industries from the oil and gas sector to food processors to agri-systems suppliers are only a few examples of the importance of irrigation to the economic and social development of southern Alberta.

One of the main benefits that irrigation use brings to the region is stability. The assurance that water can be available and can be delivered to areas that otherwise would find it nearly impossible to secure has meant a regional growth that is generally understood to be three to four times what it might be otherwise. With increasing water use efficiencies comes a greater sense of that stability. Knowing that water is being more prudently used means that there is also an understanding that opportunities may exist for water to be used to increase economic growth, to lessen the risks of water supply shortfalls, or to reduce diversions from source-rivers and help to rejuvenate deteriorated aquatic ecosystems.

However, it is acknowledged that the use of water supplies by irrigation, particularly within the southern regions of Alberta, has impacted the natural river systems. While it is virtually impossible to revert to the pristine conditions prior to these developments, some off-setting environmental gains have been made through the presence of water bodies and conveyance systems associated with irrigation, in what would, otherwise, be dry semi-arid plains.

The irrigation sector has recognized the desire and need to rejuvenate stressed water bodies, where operationally feasible, and is working with many agencies to facilitate adjustments, changes and enhancements. For example, the irrigation sector is proposing and cooperating with AENV water management operations to try and optimize irrigation diversions to the benefit of on-stream and off-stream storage gains but also for the well-being of the source-rivers' ecosystems. In one undertaking, with respect to the Oldman Dam and Reservoir, it is proposed that diversions be managed to optimize the amount of water diverted and stored during periods when the riverine aquatic environment is less sensitive to reduced flow, in order to reduce diversions during periods when the riverine aquatic environment is more sensitive to low-flow conditions.

It is recognized that aspects such as improved wetland or wildlife habitat development are water-use outcomes that can be measured to some degree. Similarly, additional park and recreational developments that are water-based and are supported by diversions from or through irrigation works could be quantified to some amount to reflect an increase in environmental benefits. Aspects such as improved health of river systems, resulting from reduced or modified withdrawals that enhance the river environment, are more difficult to quantify due to the need for longer-term assessments. A comparison of the status of regulated versus naturalized river flows could serve as an interim proxy measurement of the outcomes from accrued CEP gains. These outcomes would be quantified or qualified as *Productivity* gains.

As was indicated in Section 4.2.4, small gains in water-use efficiency within the irrigation sector can yield significant volumes of water being potentially available for various other uses. A policy and procedure could be developed that would define an evaluation process to determine the most advantageous purpose for the use of saved water. One of those beneficial uses, at least in part, may be deemed by the Alberta public to be the enhancement of flows in source-rivers. Opportunities may be created, where it can be demonstrated that water can or is being saved, for alternate-use interests (e.g. water conservancy groups) to acquire that water, through negotiated transfer, to the benefit of both the relinquishing and the acquiring parties.

5. CEP Plan Implementation and Monitoring

5.1 Implementation Schedule

As the irrigation sector is comprised of 13 independent irrigation districts and a multitude of individual private irrigators, a formalized plan of implementation has yet to be defined and coordinated. With approximately 9,000 individual irrigators involved, the task of implementing CEP opportunities will be challenging.

It is recommended that the sector continue its efforts to establish a framework wherein it can explore, with other industry partners, opportunities to move forward with CEP initiatives that have been identified within this plan.

5.1.1 Implementation Actions

In order to move this plan forward, significant education and awareness efforts will need to be initiated. As the AIPA is the identified champion of this plan, the initial education undertaking should be promoted through this organization. Obtaining sufficient resources, both technical and financial will be a challenge, but creating awareness is a necessary ingredient in moving this plan forward, particularly considering the vast numbers and varied backgrounds of the irrigation practitioners. This activity will need to be one of the major focuses so as to help irrigators become increasingly involved and committed to achieving the CEP targets.

Alliances will need to be formed with appropriate agencies that can provide leadership functions necessary to enable further technological development that can lead to further water savings. The AIPA has a history of entering into such partnerships and it will continue to collaborate when and as beneficial to the sector's achieving its CEP goals.

Individual irrigation districts have, in various ways, participated in research or pilot projects that test the application of new products, systems and concepts. These types of project collaborations will need to be continued and perhaps expanded, requiring a commitment of additional resources.

Above all, financial and human resources will be required in order to implement the above actions and accomplish the objectives of plan implementation. The current appropriations in this respect within the AIPA or at the individual district level are limited. Therefore, acquiring funding to enable these actions will need to be a high priority. However, before that can be approached, a focused CEP implementation action plan and budget will need to be formulated.

5.2 Integration with Other CEP or Water Management Plans

The irrigation district community is very much involved within both the Oldman Watershed Council and the Bow River Basin Council. This provides opportunities for extensive integration of irrigation-related water use issues with the planning and advocacy efforts of the varied interest groups represented within the Councils. It would be advantageous if there were more representation from the private irrigation group on these bodies.

The irrigation districts have working arrangements with AENV so that diversions and reservoir management can satisfy water user demands and required river flows. This relationship is invaluable and should be nurtured to allow new initiatives related to CEP opportunities to be implemented successfully.

The irrigation districts are also conveyors of water to various other water use sectors. Interaction between them requires good communication, planning and cooperation. A very successful example of how the irrigation district community has worked through such conditions is the water-sharing and rationing of water that was necessary and implemented during the extensive drought of 2001. (This is further detailed in Appendix G).

5.3 Monitoring and Reporting of CEP Progress

The irrigation district community has demonstrated a thorough process of data collection and statistical reporting with the assistance of AARD. Gathering of this information will continue to be invaluable as monitoring of water use and determination of improvements require documentation. More rigorous accounting and publishing of information related to the quantities of water delivered to other users or conveyed to other licensees will help to demonstrate irrigation sector support to a variety of stakeholders and also better define the reported diversion amounts that are attributable to irrigation only.

The sector has demonstrated a track record for water use improvements. This plan sets out a framework of benchmarks from which to measure progress and identify targets to achieve. In cooperation with the Water Resources Division of AARD, the statistical information published and its use in developing the goals and targets are invaluable. It is proposed that AARD, in close partnerships with individual irrigation districts and the AIPA, can fulfill the important role of monitoring CEP progress and developing annual auditing of the collected data.

Through the contributions of data from each irrigation district, AENV and other agencies, AARD has annually published the statistical report, Alberta Irrigation Information, on behalf of the irrigation sector and all agencies with direct involvement. It is proposed that additional components can be devised to facilitate the annual reporting of water use in the context of meeting the targets that have been identified in Section 4.3 of this document.

As emphasized previously, the variability in irrigation water use, from one year to another, makes annual analyses somewhat uncertain as to the progress being made. However, the rolling-average approach appears to be a reasonable concept for interim assessments. Realistically, a more comprehensive review of CEP gains can be obtained at five-year intervals. During the course of that time, better indications of such external factors as cropping tendencies, climate change effects, systems improvements and developments of new technologies may be available.

6. CEP Plan Participation and Accountability

There are currently no specific agreements or directives in place that require irrigation sector or irrigation district alignment or compliance with this CEP Plan. However, the irrigation sector has entered into this process in good faith because of the mutual interest in achieving the best use of the province's water resources.

There are 13 irrigation districts, each with a unique operating situation in southern Alberta's extensive irrigation water distribution systems. Similarly, private irrigators have their own varying and unique circumstances to manage. One approach or solution does not necessarily fit all situations.

Despite their being no formal agreements in place with regard to any specific requirements for the sector to move forward, it is advisable that, through organizations such as the AIPA, each irrigation district be encouraged to develop its own specific CEP plan that is complementary to the goals and targets outlined within this report. These can serve as a framework on which to derive further sector commitment, which may return dividends in outside agency and broader government support.

As is summarized within the final guiding report concerning sector CEP planning (AWC 2008):

"The expectation is that individual members of each sector will take direction from their sector's overarching plans and develop CEP measures for their own operations. In certain instances, individual water licence holders will wish to develop a formal plan. Just as the sector plan will contribute to achieving Alberta's overall CEP goals, as stated in the Water for Life strategy, each individual member's actions will help that sector meet its goals and targets. In most cases, a formal sector association will lead the development of CEP plans. In sectors where a formal association does not exist or where not all members of a sector are represented by an association, collaborative processes will be used to develop CEP plans."

7. CEP Plan Summary and Recommendations

7.1 Summary

The development of irrigation in Alberta has brought about significant economic and social development unique to the southern region of the province. Irrigation is more than just the production of diverse agricultural commodities. The capability of the irrigation delivery systems to store and convey water to and within areas that otherwise lack access to sufficient supplies of good quality water has meant that other uses, such as municipal, industrial, other agricultural uses, rural water supply, wildlife habitat and recreation have been able to become established and realize continued growth as well.

While the opportunities for productivity growth have increased, it has not been accomplished without placing significant demands on the natural water supply system. As irrigation is the largest consumptive user of water in the province, it is incumbent on the irrigation sector to be diligent in its use of the limited resource. Through the past 50 to 100 years of irrigation development, the large diversions required for irrigation have had noticeable degrading impacts on some river reaches. Recent revised water management operations have provided some relief to the strain on the rivers, but there still is some degree of impact on those natural flow regimes and the aquatic ecosystems that they support. Reduced diversions during critical river flow periods will help to mitigate some of those impacts. Depending upon where future water savings are directed, desirable diversion reductions at critical times may also be aided through expanded storage capacity.

It must also be recognized that irrigation conveyance and storage systems have also fostered the development and enhancement of other water-related environmental conditions that otherwise would not exist. Nonetheless, as a major goal in developing sector CEP plans is to realize improvements to aquatic ecosystems from which sectors derive their water, it is incumbent upon the irrigation sector to seriously consider how it can turn at least a portion of the projected efficiency gains into improvements in the river ecosystems.

Through the last four decades, the irrigation sector has achieved a three-fold increase in its water-use efficiency. This has occurred, in large part, because of the change in irrigation practices at the farm level, where more sophisticated application technologies have been adopted. During the same period, extensive rehabilitation of irrigation water conveyance systems has contributed to reducing seepage and evaporation losses and to overall improvements in water control which has helped to reduce return flow volumes.

The coming challenge for the sector is to determine where and by how much it can add to the efficiency increases. This report documents the gains made up to this time and has suggested the goals and objectives for continued improvements. The sector needs to continue to enable further water use efficiency gains, productivity growth, and enhancement of environmental resources.

Through the next 10 to 15 years, it may be possible for the sector to increase its water use efficiencies by as much as **9.4 percent**. This is equivalent to an overall improvement multiplier of almost 1.2 from 2005 levels and could result, on average, in reductions of up to **15 percent** in the annual gross irrigation diversion demand. The accumulated gains would largely be derived from continuing on-farm system up-grading and from the reduction in return flows, primarily achieved through conveyance system rehabilitation and expansion. Water saved could be re-directed into other areas such as irrigation area growth, off-setting potential climate change effects, shared with other users to increase their productivity, or towards environmental benefits.

Although the 9.4-percent gain in irrigation water use efficiency, accompanied by possible reductions in average diversions of up to 15 percent, appears to be a realistic challenge, it does fall considerably short of the *Water for Life* outcome of a 30-percent improvement in water use efficiency and productivity. With the understanding that this target is a proportional increase, based on the 2005 efficiency level of 53.3 percent, a 30-percent improvement would anticipate an overall efficiency gain of approximately 16 percent in irrigation water-use efficiency. Therefore, the 30-percent improvement target is likely unreachable by 2015, or beyond, unless incremental gains beyond the 62.7-percent efficiency level that has been projected can be achieved through productivity gains.

It is suggested that the irrigation sector commit to limiting its overall irrigation use diversions to that volume associated with the year 2005 as derived through the 10-year rolling-average, noting that, in any given year, as conditions may dictate, diversions may need to exceed that determined value. This report has demonstrated that with continued efficiency gains, averaging around 0.65 percent per annum, restricting rolling-average diversions to this benchmark volume is possible. However, as there are uncertainties for the future, such as the potential effects arising from projected global warming or shifts in crop mix due to changing market conditions, it is recommended that the targets be re-evaluated at five-year intervals.

It is further suggested that the sector strive for gains in efficiency indicated by a continual reduction in the unit area diversion amount, as determined through 10-year rolling-average derivations. However, such reductions will only be possible to a certain level as they are limited by the basics of satisfying crop water requirements.

7.2 Recommendations

In the development of this plan and examining opportunities for gains in water use conservation, efficiency and productivity, specific outcome ***targets*** have been identified. It is recommended that the irrigation sector adopt these targets, listed as follows.

1) That the annual gross irrigation diversions, totalled for all irrigation districts and calculated as 10-year rolling-average volumes, not exceed 2.186 billion cubic metres.

2) That, within the next 10 to 15 years, the annual gross irrigation diversions, averaged for all irrigation districts and calculated as 10-year rolling-average depths per unit of irrigated area, will continue to decrease from 441 millimetres to a target level of approximately 385 millimetres. A comparable target for private irrigation projects, ***on average,*** is recommended to be 320 millimetres. (Note: Just as the

target for irrigation districts is based on overall conditions across all districts, so must the target for private irrigation operations be considered. In other words, some individual private operations, due to crop mix for example, will require a greater amount of water to be diverted while other operations will be producing crops that will require lower amounts of supplemental moisture through irrigation.)

3) That the total amount of return flow, averaged for all irrigation districts, be reduced to half of the 2005 rolling-average amount of 86 millimetres to 43 millimetres per unit of irrigated area, within 10 to 15 years.

4) That, within the next 10 to 15 years, the average level of overall irrigation efficiency within the irrigation districts is increased from the current level of nearly 54 percent (year 2005) to almost 63 percent. This nine-percentage point gain equates to approximately a 17-percent improvement from the base reference year (2005) efficiency level.

5) That, by 2015, the currently measured long-term average productivity trendline, expressed as units of commodity produced per unit of water diverted for the irrigation of sugar beets, potatoes and soft white spring wheat, increase from 8.8 kilograms per cubic metre (year 2005) to at least 10 kilograms per cubic metre. This increase would equate to approximately a 14-percent improvement from the base reference year (2005) productivity measurement.

The following are general recommendations that are intended to help guide the irrigation sector in adopting and implementing this CEP plan. Much of the future potential gains will only be achievable with the concerted effort of all irrigation districts, irrigation producers, other water users and government agencies. In order for the irrigation sector to better implement this CEP plan and achieve the recommended preceding targets, it is recommended that:

1) The Alberta Irrigation Projects Association provide guidance and encouragement to the Alberta irrigation district community, to enable each of the 13 districts to develop its own Water CEP strategy that is complementary to this Sector planning document. Each district's strategy should be specific to the district's development and operational conditions. (For example, to date, some districts have been able to make much more progress in CEP gains than others by already increasing their efficiency to near the maximum possible with current technology, thereby possibly being limited in the amount they can increase their efficiency further. Other districts have the potential to accomplish more. The districts should work together to collectively achieve the overall targets projected for the sector.)

2) The irrigation districts, through the AIPA and with the assistance of AARD, develop a strategic plan for the on-going evaluation of progress toward achieving CEP gains.

3) In collaboration with such agencies as AARD and in consultation with other stakeholders, it is recommended that the irrigation districts and private irrigators embark on a process to develop a much broader approach to measuring productivity gains.

4) The AIPA establish a formalized process of providing awareness and education with respect to the implementation of this plan, collaborating with AARD, as appropriate for both agencies, in developing information products, convening workshops, and directing information to irrigators, irrigation districts and other users relying on the irrigation system.

5) The private irrigation communities develop or formalize representative organizations, likely based around common watersheds or river sources and linked into respective WPACs, so as to be able to address related water uses on a broader scale to other stakeholders and government agencies.

6) Irrigation districts, the AIPA and private irrigators enter into cooperative agreements with technical partners to enable the development and execution of specific CEP research and development projects. Such projects could include the introduction of new conveyance monitoring and control technologies; the adoption of higher-efficiency water application devices or systems; the application of water delivery measurement and accounting systems; the application of deficit irrigation management principles; and the development of crop alternatives that may be more efficient in their consumptive use of water, just to name a few.

7) Irrigation districts expand and enhance the recording and reporting of their water operations data. One objective in doing this would be to better distinguish between flows directed specifically to irrigation purposes and those quantities delivered for other uses.

8) Irrigation districts expand and enhance, where necessary and advantageous, the rigorous and consistent monitoring and reporting of return flows from their operations.

9) Irrigation districts that have not already done so, implement a comprehensive policy and field program of restricted limits on water deliveries to irrigators that will encourage water conservation on the part of end-users. For those districts that have previously instituted this type of mechanism, it is recommended that these pre-existing water operation constraints be thoroughly evaluated to assess their effectiveness in truly encouraging water conservation and to determine opportunities for related enhancements.

10) In cooperation with other water management and research and development agencies, private irrigators and AENV derive water measurement and tracking systems that can be incorporated into private irrigation projects to better monitor and quantify water use by private irrigation operations.

11) The irrigation district community investigate collaborative opportunities through agencies such as Alberta's Irrigation Council or Capital Planning Initiative (CPI), and the Agri-Environment Services Branch of Agriculture and Agri-Food Canada (formerly PFRA) to acquire additional funding for the rehabilitation of irrigation infrastructure, targeting this additional funding to support projects which emphasize the re-development of works where efficiency and potential productivity gains can be optimized and demonstrated.

12) Consideration is given, by appropriate provincial and federal jurisdictions as well as by irrigation districts, to implement incentive programs, which will enable irrigation producers to up-grade their on-farm systems to higher-efficiency technologies. (E.g. strive to achieve the desired development target of having 80 percent of the irrigated area within and outside the irrigation districts irrigated by some form of centre pivot sprinkler system.) Alternatively, capital improvements could be made to existing systems where conversion is not feasible. (E.g. for surface irrigation schemes, adding tailwater pump-back systems or gated-pipe deliveries.)

13) Where efficiency gains can be demonstrated, that irrigation districts and private irrigators give consideration to utilizing water marketing opportunities for the apportioning of licence allocations to benefit economic growth in other sectors and/or for the enhancement of aquatic environment conditions or wildlife habitat.

14) While irrigation area expansion is seen as one of several options for the potential productive use of saved water, such expansion should be approached with due care and attention to the unpredictability of future climate situations and the projections for potentially warmer and drier conditions.

15) Irrigation water conveyance agencies such as AENV and irrigation districts develop their water conveyance systems to minimize, as much as possible, the entrance of surface water run-off into these systems. This is intended to reduce land surface contaminants from entering the delivery systems, helping to sustain water quality in both irrigation deliveries and return flow.

16) The irrigation sector collaborate with AENV, Alberta Sustainable Resource Development (ASRD) and other affiliated or interested water resource management agencies in Alberta, to determine opportunities to augment river diversion operations that can take advantage of periodic high river flows through the optimization of diversions into storage during those periods, thereby reducing the need for large diversions during natural low-flow periods.

17) The irrigation sector schedule a formalized review of its CEP plan, on a five-year cycle, in order to document progress toward CEP goals and to make adjustments in benchmarks and targets as necessary and appropriate.

18) The irrigation sector continues the dialogue with other stakeholders to develop mutually-acceptable and beneficial opportunities for increased water use conservation, efficiency and productivity.

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Appendices

The following listing outlines the contents of appendix material referenced in this report but compiled under separate cover, ("Irrigation Sector -Conservation, Efficiency and Productivity Planning Report – Appendices").

Appendix A: Steering Committee Membership and Terms of Reference

Appendix B: Table of Irrigation District Licences

Appendix C: Climate Change & Irrigation Water Use Projections

Appendix D: Understanding Numeric Water Use Efficiency Expressions

Appendix E: Irrigation District Supply of Water to Other Uses

Appendix F: On-Farm Irrigation Efficiency Factors and Analyses

Appendix G: Summary of Irrigation District Water-Sharing Strategy - 2001

Appendix H: Irrigation Water Use and the SSBWAR ("The Regulation")

Appendix I: Summary of Stakeholder Workshop

Appendix J: A Review of CEP Initiatives from Other Jurisdictions

Glossary of Terms Used in this Report

Application Efficiency: The ratio of the amount of water that is distributed to an irrigated field and that is actually available in the soil root zone for use by the irrigated crop, relative to that total amount of water that is distributed to the irrigated field by some form of application methodology.

Apportionment: An amount of water, measured as either as an identified volume or as a proportion of a volume of water that is committed to being supplied to an adjacent jurisdiction through a formalized sharing agreement. For example, Alberta and Saskatchewan are signatories to an apportionment agreement for water that arises within the South Saskatchewan River Basin within Alberta that must flow into Saskatchewan each year.

Aquatic Ecosystems: The holistic environment that supports plant, vertebrate, invertebrate and micro-organism life that naturally exists within and adjacent to water bodies, whether they be rivers, creeks, lakes, marshes and the like.

Benchmark: Defined as a measurement or standard that serves as a point of reference by which the performance of a process, of components or of a system is measured. Benchmarks are used for comparing performance in an effort to identify progress being made and to identify more efficient and effective processes for achieving intended results.

Consumptive Use: Water that is used for the intended purpose but then is no longer available for re-use (e.g. crop evapotranspiration, oilfield injection, etc.).

Deficit Irrigation: The practice of applying less irrigation water to a crop than it would normally require or consume but providing a lesser amount that ensures sufficient water is available at critical production stages so that yields may be optimized rather than maximized and less water used overall. Within acceptable production yield levels, the intent is to realize higher commodity output relative to the amount of water consumed.

Demand Management: The practice of applying specific water management techniques, in a water use situation, that confines the degree of demand with a goal to minimizing the overall water required to achieve the objective of the water use.

Evapotranspiration: The combination of the physiological process of water consumption by plant life for transpiration functions and the physical process of water being evaporated from the plant (or crop) canopy and from the soil surface supporting the plant growth.

Gross Diversion: The full amount of water that is actually withdrawn from a supply source and represents all water required for consumption purposes, losses and return flows.

Gross Irrigation Diversion Demand (GIDD): The theoretical or computed demand for water, either as a volume or as a rate of flow, for any given time period, that quantifies the predicted gross diversion from the source of water that would be required to satisfy all irrigation-related requirements, including application, storage and conveyance losses, as well as projected return flow.

Irrigated Area: The field area, within any given irrigation season, which actually receives one or more applications of irrigation water.

Irrigation Area: The field area, within any given irrigation season, which is authorized to be irrigated, but which may or may not actually receive one or more irrigation applications.

Instream Flow Need (IFN): The scientifically-determined amount of water, flow rate, or water level that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation or aesthetics. An in-stream need is not necessarily the same as the natural flow.

Licensed Allocation: The defined volume of water that has been authorized, according to provincial government statute, to be diverted for an approved use through the course of a defined period of time, usually not exceeding one year. The allocation could include specific conditions relating to timing of diversions, rate of diversion, restrictions subject to in-stream flows, etc.

Losses: Water that is included as a component within an allocation that can be withdrawn for a particular use, but may become unavailable, either through evaporation, seepage, or unrecoverable return flow and as a result is not available for immediate re-use.

Return Flow: An amount of water that is included in an allocation that is expected to be returned to a watershed after use and may be available for re-use, although the water quality characteristics may have changed during use. Not all return flow is necessarily returned to the original source of diversion or withdrawal.

Rolling-Average (10-year): The average of a time-series of data points that reflects re-computed averages of successive consecutive groupings of data. In the case of 10-year rolling-averages, the annual amounts of each of the 10 years of the initial grouping, starting in year “X”, are averaged, followed by a computation of the average of the succeeding ten-year grouping, beginning at the year “X+1”, and so on. Rolling averages are applied to attempt to reduce the apparent interpretive effects of spikes or depressions in data series in order to generate a more realistic picture of trend lines.

Supply Management: The practice of applying specific water management techniques, in a water use situation, with a goal to ensuring that sufficient water is supplied to meet all water withdrawal and use demands, regardless of the demand or supply conditions.

Target: A measureable quantitative value or qualified condition that defines a goal to be strived for and achieved as an outcome of an implemented process.

Water Availability: The portion of a water supply that can be effectively utilized for specific withdrawal or in-stream purposes. For example, water that flows through a system under flood conditions cannot usually be utilized for specific diversion intentions and so is unavailable to that purpose. The "water availability" is always equal to or less than the "water supply".

Water Allocation: The amount of water that may be diverted for use, as set-out in water licences and registrations issued in accordance with the Water Act. Allocations include a maximum volume of water that can be withdrawn from a water source, as well as the rate of withdrawal, the identity of the water source, the purpose for which the water is to be used and the location at which the diversion can occur. Allocations reflect the amount of water that will be consumed plus any losses that might occur, and may include an allowance for flows that are returned after use. An allocation is generally based on the maximum amount of water that a licensee expects will be required on either an annual basis or through the licensing period.

Water Conservation: A philosophy within water use that aspires to create an ethic within the water-user community that will be reflected in water being diverted and consumed at reducing levels to achieve the intended purpose. A goal of increasing water-use efficiencies would be a reflection of an ethic toward water conservation.

Water Diversion (or withdrawal): Describes the amount of water being removed from a surface or groundwater source, either permanently or temporarily. Water diversions may be less than or equal to water allocations and may include an allowance for some water to be returned to water bodies after use.

Water Productivity: The amount of water that is required to produce a unit of any good, service or societal value.

Water Supply: Generally considered to represent the total amount of water that is generated (e.g. precipitated) within a watershed through a defined period of time (usually annually) that flows through, is retained within or is lost from the watershed through evapotranspiration and deep sub-surface percolation; and is the total amount from which water users can attempt to withdraw their authorized allocations. This can apply to both surface and groundwater. The "water supply" is always equal to or greater than the water "availability".

Water Use: Considered to be the combination of actual water consumption plus losses associated with a diversion, or, alternatively, represents the difference between the amount of water actually diverted and the return flow.

Water Use Efficiency: An indicator of the relationship between the amount of water needed for a particular purpose and its ultimate end result versus the total quantity of water diverted for that purpose to achieve that result.

Acronyms Used in this Report

AARD	-	Alberta Agriculture and Rural Development
AENV	-	Alberta Environment
AID	-	Aetna Irrigation District
AIPA	-	Alberta Irrigation Projects Association
BRID	-	Bow River Irrigation District
EID	-	Eastern Irrigation District
GCM	-	Global Climate Model
GIDD	-	Gross Irrigation Diversion Demand
IDIMS	-	Irrigation District Infrastructure Management System
IDM	-	Irrigation Demand Model
IPI	-	Irrigation Productivity Index
IRP	-	Irrigation Rehabilitation Program
IWMSC	-	Irrigation Water Management Study Committee
LID	-	Leavitt Irrigation District
LNID	-	Lethbridge Northern Irrigation District
MID	-	Magrath Irrigation District
MRB	-	Milk River Basin
MVID	-	Mountain View Irrigation District
RCID	-	Ross Creek Irrigation District
RID	-	Raymond Irrigation District
SMRID	-	St. Mary River Irrigation District

SSBWAR	-	South Saskatchewan Basin Water Allocation Regulation
SSRB	-	South Saskatchewan River Basin
TAU	-	TransAlta Utilities
UID	-	United Irrigation District
WID	-	Western Irrigation District
WRMM	-	Water Resources Management Model

Unit Conversion Chart

Area:	1.0 hectare (ha)	=	2.471 acres
Length or Depth:	1.0 millimetres (mm)	=	0.0394 inches
	1.0 metre (m)	=	3.2808 feet
	1.0 kilometres (km)	=	0.6214 miles
Rate of Flow:	1.0 cubic metre per second (m^3/s)	=	35.315 cubic feet per second
	1.0 litre per second (l/s)	=	15.85 US gallons per second
Volume:	1.0 cubic metre (m^3)	=	35.315 cubic feet
	1.0 million cubic metres (million m^3)	=	810.713 acre-feet
Weight:	1.0 kilogram (kg)	=	2.2046 pounds
	1.0 tonne (T)	=	1.1023 tons
Yield:	1.0 kilogram per hectare (kg/ha)	=	0.893 pounds per acre
	1.0 tonne per hectare (t/ha)	=	0.446 tons per acre