Irrigation Water Balance Modelling: Better Landscapes Through an Improved Design Process

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Abstract. *It is generally agreed that water is a limited resources. 97% of the world's water is saline; we have a long and well documented history of abusing this resource/an almost exponential rise in human water use because of increases in population and per capita water use in the last 75 years. Climate change/global warming has simply exacerbated the problem.*

Landscape irrigation is based primarily on potable water sources. Recent initiatives to improve the efficiency of landscape irrigation design and products have reduced irrigation water consumption. Although admirable, these initiatives do nothing to address the problem/disease rather than the symptoms. The only way to start addressing the issue is to truly understand how much irrigation water will be required before the landscape design is finalized.

In its simplest form, Irrigation Water Balance Modeling, or IWBM, is an irrigation water consumption calculation based on plant water use, on a species by species basis, microclimate, soils and seasonally available precipitation information. This calculation allows us to accurately predict quantify daily, weekly, monthly and seasonal irrigation water requirements for a given landscape design early enough in the design process that the irrigation water design consumption can be quantified and potentially reduced through the elimination of irrigation in non-essential area and/or the substitution of less water consumption species. Only by understanding these factors can we design landscapes that are viable without continuing to overdraw on our water resources.

Keywords. Designer/Consultant, Policymaker, Water Manager, Water Provider, Turf/Landscape (Commercial), Turf/Landscape (Residential), Drip, Sprinkler, Deign, Conservation, Sustainability, Alternate & Alternative Water, Rainwater, Reclaimed & Recycled Water, Controllers, Turf/Landscape Smart Controller, Drip/Micro Systems, Turf/Landscape, Rain Sensor/Shut Off Switches, Rain Water Harvesting Equipment.

Introduction

What is Irrigation Water Balance Modelling (IWBM)?

- IWBM: Consumption calculation based on site specific criteria.
- Accurately quantifies irrigation water requirement.
- Accurately predict supply/availability with demand.
- New design parameters: L.I.D. and L.E.E.D.
- The rising cost of water.

Water Issues in General

About 1/3 of the world's population live in arid regions. That factor coupled with the acceleration of frequency of extreme weather events globally, as a function of climate change has resulted in extended periods of "atypical" weather everywhere. What does this mean? "The world is facing a crisis in water instability and is just walking up to the idea" (Dr. Howard Wheaton, 2013). In California the Sierra snow pack provides 75% of the annual freshwater supply. Similar to

Canadian Glaciers the Sierra snow peak is shrinking. If precipitation across the Sierras falls by 1% reservoir volumes by 32%.

The Prairie Provinces represent one of the most extreme “agricultural” climates in the world. 80% of Canada’s agriculture and important mineral resources are situated in the Saskatchewan Rivers basin. In some parts of the basin the water supply is already fully allocated and is additionally threatened by damaging floods and draughts as well as deteriorating water quality. “Water futures depend on what society chooses” (Dr. Howard Wheaton, 2013)

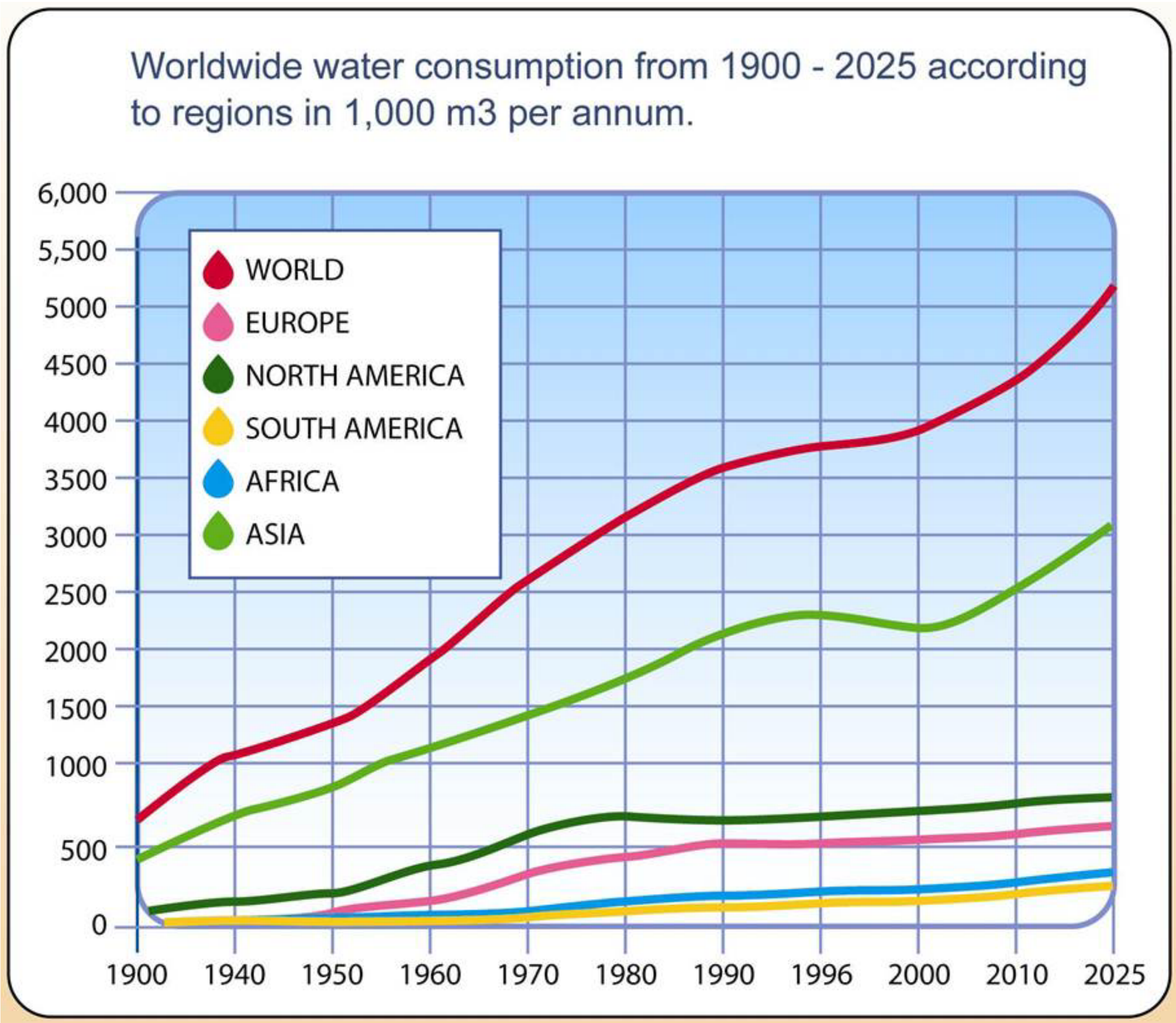

Figure 1. Worldwide water consumption from 1900 – 2015 according to regions in 1,000 m3 per annum.

In their report “GEO 2000,” the United Nations Environment Program UNEP states, that:
In the year 2000

- One third of the world’s population (more than 1 billion people in 21 countries) will not have a sufficient supply of potable water.
- Every year, more than 7 million deaths occur as a result of water pollution or scarcity.

In the year 2025

- Two-thirds of the world's population (more than 2.5 billion people) will not have sufficient potable water.
- 70% of crops worldwide will be produced with irrigation.
- China will consume 78% of its water supply for agricultural purposes, and India an even higher 93%

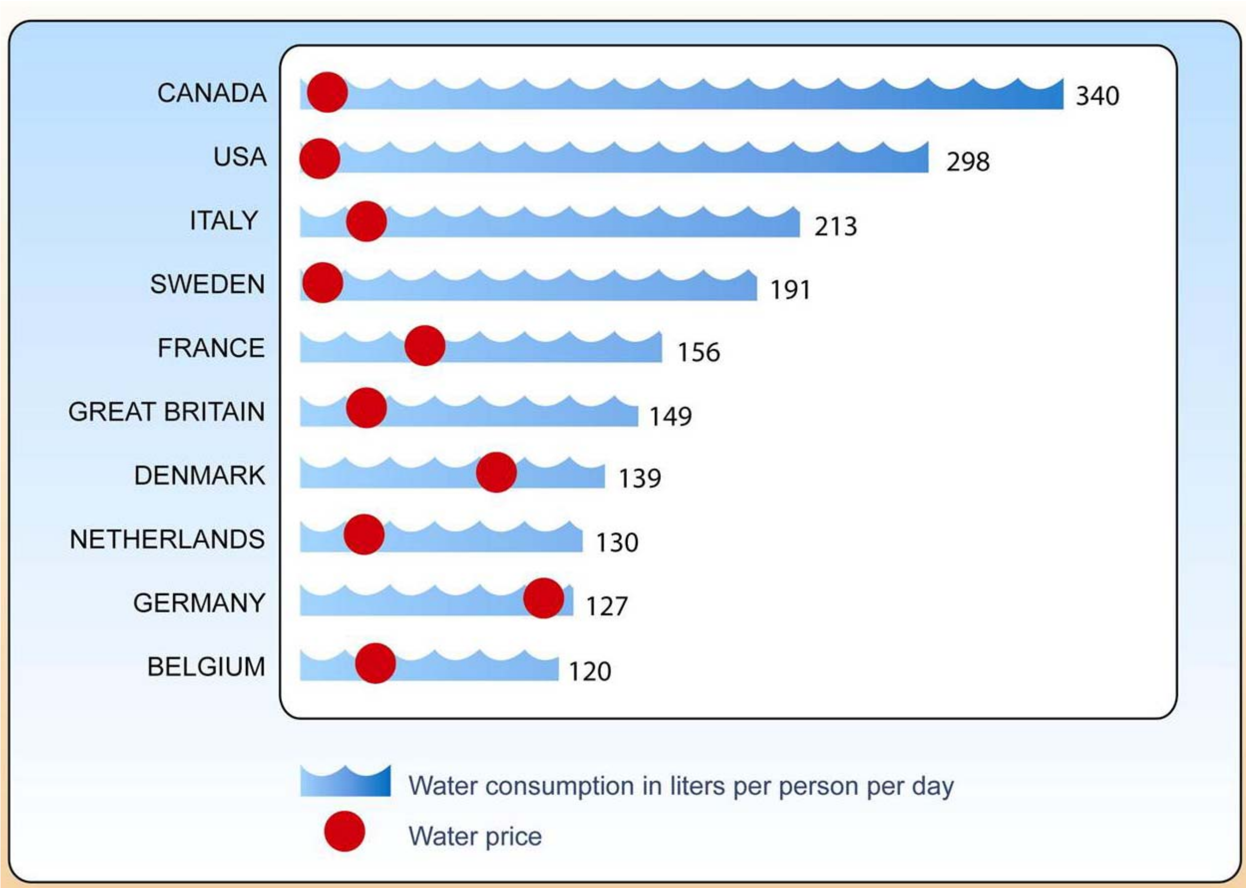

Figure 2. Regional Per Capita Water Use

The Amenity Landscape Industry

Every level of society is being sensitized willingly, or otherwise, to the increasingly precarious nature of our water reserves. In Canada we have been blessed with a historical surplus of freshwater reserves. Because of this, as a result public will continue to overdraw this reservoir (per capital Canadians triple the water use of most Europeans). Not specifically because of this issue, but over the last 20 years the major amenity irrigation manufactures have dramatically the efficiency and control potential factors of their product lines. Unfortunately as design industry landscape architects have not been as proactive as we could be in terms of translating these product improvements into more water "cautious" landscape designs. We are going to hit a wall in the not too distant future so my recommendation is to get in front of this challenge as soon as possible. Irrigation Water Balance Modeling has the potential to move us significantly in that direction.

Irrigation Product Innovations

In general these innovations can reduce or eliminates water waste and promote healthier plant growth:

- Match the water application to the specific needs of each plant.
- More closely match the application rate to the soil's infiltration rate.
- Apply water directly to the root zone to reduce overspray and evaporation.
- Reduces or eliminates runoff.

General Irrigation Design Considerations

- Available irrigation water volume
- Available water pressure
- Site soils
- Size and configuration of areas to be irrigated
- Type and number of obstructions within area to be irrigated
- Type of vegetation
- Physical activities within irrigated area
- Minimizing product variety within the site

The Landscape Design Process

Figure 3. Historically

Figure 4. Irrigation Water Consumption Calculation

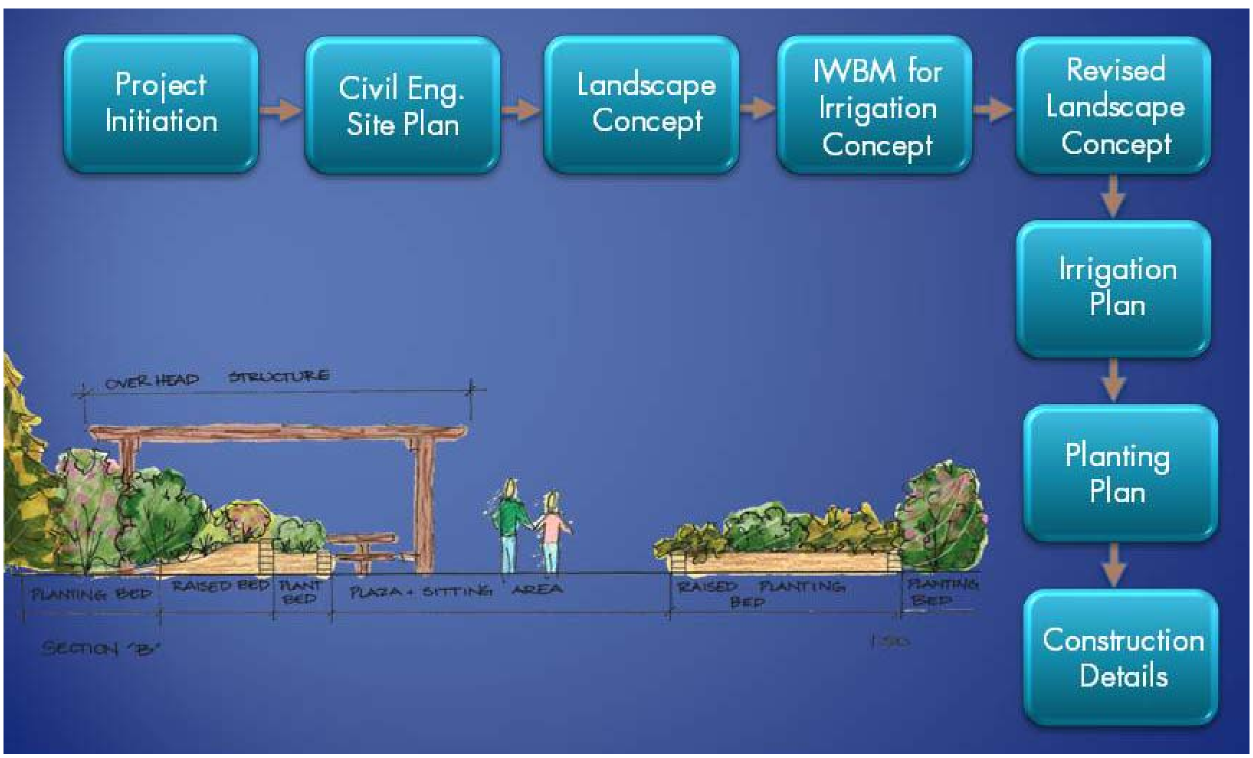

Figure 5. New Approach/Process

Figure 6. Landscape Concept

Figure 7. Irrigation Water Consumption Calculation

Environmental Considerations for IWBM

Climate/Microclimate

Table 1. General Climate Types in North America

Climate	Humidity	Avg. Max. Temp (°F)	ET (in.^{p}/day
Cool	Dry Humid	< 70 < 70	0.15 0.15
Moderate	Dry Humid	70 - 80 70 - 80	0.25 0.25
Warm	Dry Humid	80 - 100 80 - 100	0.35 0.30
Hot	Dry Humid	< 100 < 100	0.45 0.40

Microclimate Considerations

- Environmental conditions may also vary significantly within a single landscape
- "Average" microclimate: Adjacent structures, shade, surfaces, orientation and slope conditions do not influence the site.
- "High" microclimate: Sun (heat absorption/solar reflection and wind exposure overtly influence the site.
- "Low" microclimate: Shade and shelter overtly influence the site.

Precipitation

Table 2. Calgary police services 1 district weather data/site water balance

Month	Precipitation: Rain + Snowmelt (mm)	Precipitation on Site (m^3)	Harvested Water per Month (m^3)	Required Draw-down (m^3)	Obtained from Cistern (m^3)	Water Remaining in Cistern (m^3)
September Half	22.85	61.12	31.38	0.00	0.00	31.3822
October	13.90	37.18	19.09	0.00	0.00	50.4725
November	12.30	32.90	16.89	0.00	0.00	67.3653
December	12.20	32.64	16.76	0.00	0.00	84.1208
January	11.60	31.03	15.93	0.00	0.00	100.0522
February	8.80	23.54	12.09	0.00	0.00	112.1381
March	17.40	46.55	23.90	0.00	0.00	136.0353
April	23.90	63.93	32.82	0.00	0.00	168.8595
May Half	30.15	80.65	41.41	0.00	0.00	176.5000
May Half	30.15	80.65	41.41	-1.96	0.00	176.5000
June	79.80	213.47	109.60	-56.09	0.00	176.5000
July	67.90	181.63	93.25	-24.25	0.00	176.5000
August	58.80	157.29	80.76	0.09	0.09	176.5000
September Half	22.85	61.12	31.38	17.57	17.57	176.5000

Soils As

We can look at soil as a reservoir for water

Soil, in general, influences the plant's growth by:

1. Supporting and anchoring the plant
2. Supplying and storing the essential nutrients
3. Supplying and storing the plant's water needs
4. Supplying and storing the plant's oxygen needs

Soil Structure

1. Refers to the various arrangements of soil particles
2. Primary constituents/elements (sand, silt, or clay)

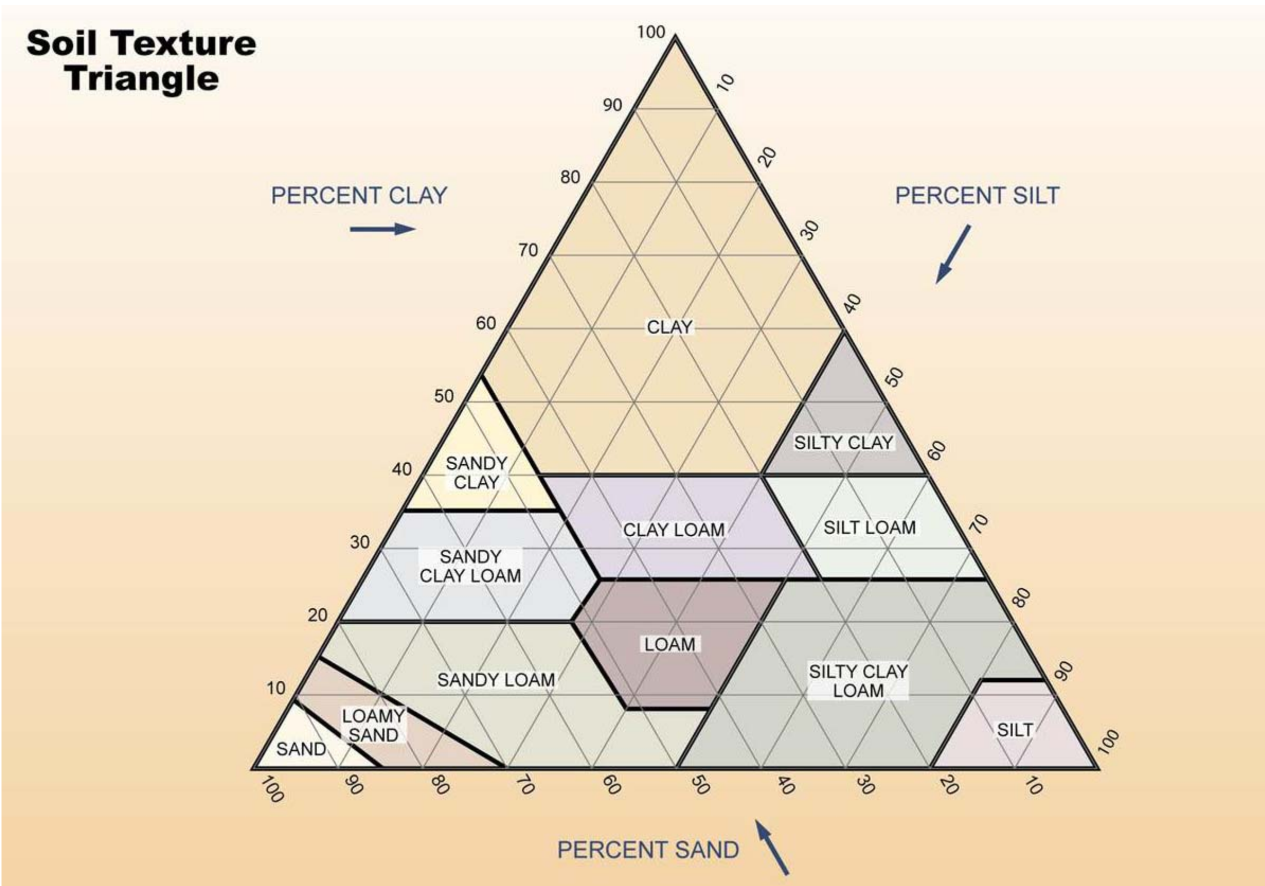

Figure 8. Soil Texture Triangle

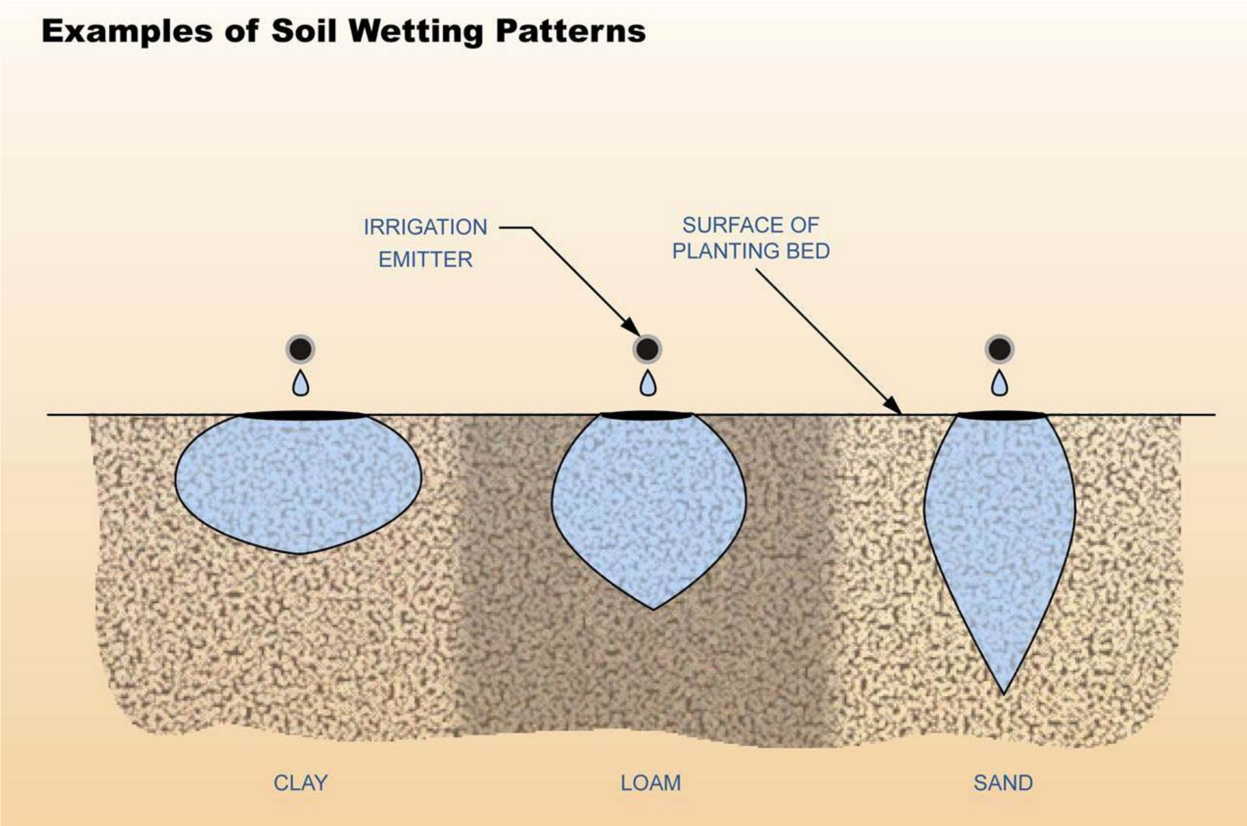

Figure 9. Examples of Soil Wetting Patterns

Plants/Plant Water Use

a) Factors which affect plant growth
b) General use characteristics

- High - Ornamented
- Average – Naturalized
- Low - Native

The difference between low water use and drought tolerance.

Plant Water Use Calculations

Plant water use is based on Irrigation Association design principals for soils, microclimate and planting density factors, as well as, plant species, character, and size at maturity.

Plant Landscape Coefficient: KL = Ks x Kd x Kmc

Where: KL = Landscape coefficient
Ks = Species factor
Kd = Density factor
Kmc = Microclimate factor

Different plant species can vary considerably in their rates of water consumption/evapotranspiration. Some species require/transpire large amounts of water, while others use relatively little.

Because there is such a wide range of water needs among different landscape plants, the water use is divided into three use groups: High, Medium, and Low, as shown below.

Table 3. Species Factor (Ks) for Different Plants

Vegetation	High	Average	Low
Trees	0.9	0.5	0.2
Shrubs	0.7	0.5	0.2
Ground Cover	0.9	0.5	0.2
Mixed Cover	0.9	0.5	0.2
Turf Grass	0.8	0.75	0.6

Calgary is classified as a cool, dry climate therefore our worst case Evaporation Rate is 0.15-0.20 inches/day. For calculation purposes species factors (Ks) for this project are keyed to actual values for local species/climate information.

The following formula is used to calculate the required maximum amount of water to apply on a per plant basis. For Trees we will assume the calculation at 75% of the plant's maximum size based on Landscape Nursery Trades Association information.

Plant Water Use: ETp = Ks x ETr (in./day)

Where: ETp = Plant Water Use (in./day)
Ks = Species Factor
ETr = Reference ET

Additional Considerations

How do LEED initiatives relate to irrigation design?

The US Green Building Council, as the governing agency for L.E.E.D. criteria in the United States, and its counterpart, the CaGBC in Canada, promote similar, but less specific, design criteria as the Irrigation Association in terms of irrigation water conservation.

LEED Design Considerations are divided into five key performance categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality

A sixth category: Innovation and Design Process rewards exceptional environmental and/or design performance.

LEED Point System: Certified/Silver/Gold/Platinum

From an irrigation design standpoint, we can contribute to the Sustainable Sites, and Innovation categories, but most significantly in Water Efficiency category:

WE 1.1

The intent is to limit the use of potable water for landscape irrigation to 50%. To achieve this point, potable water consumption for irrigation purposes must be reduced by 50% over conventional means by using captured rain or recycled site water.

WE 1.2

The intent is to eliminate the use of potable water completely for landscape irrigation purposes. This point is achieved by using **ONLY** rainwater or captured site water as the source for irrigation water.

L.I.D. or Low Impact Development Parameters

What is L.I.D.?

In it’s most basic sense and as it applies to this discussion, L.I.D. is the matching of post development storm water flows to pre-development storm water flows.

What does it mean?

In terms of storm water design it means an increase, on a community by community basis, in storm water retention/detension facilities and storm water engineers are generally looking for every means possible to lose volume out of these facilities without putting it directly into conventional storm water systems based on the general premise of recharging the groundwater system. What this means to irrigation design is that we need to look harder at non-potable irrigation water sources, such as storm ponds.

Non Potable Water Sources

- L.I.D. – Required drawdown vs. irrigation consumption
- Rain Water Harvesting – allowable drawdown vs. irrigation consumption

Irrigation Control

IRRIGATION SCHEDULE CHART

STATION/ZONE	ZONE VALVE	PSI AT VALVE	HEAD TYPE	NOZZLE NUMBER	FLOW (GPM)	PRECIPITATION RATE (IN/HR)	SLOPE	ASPECT	SOIL	JUNE 1 -- AUGUST 30: TOTAL RUN TIME (min)	DAYS OF THE WEEK	NUMBER OF CYCLES	CYCLE TIME (min.)	SOAK TIME (min.)	SPRING - FALL: TOTAL RUN TIME (min)	DAYS OF THE WEEK	NUMBER OF CYCLES	CYCLE TIME (min.)	SOAK TIME (min.)
1	38mm	45	ROTOR	2.8/4.0	30	0.48	YES	SOUTH	CLAY LOAM	153	MWF	3	17	75	108	MWF	3	12	16
2	38mm	45	ROTOR	2.8/4.0	34	0.48	YES	SOUTH	CLAY LOAM	153	MWF	3	17	75	108	MWF	3	12	16
3	38mm	45	ROTOR	2.8/4.0	30	0.48	YES	NORTH	CLAY LOAM	153	MWF	3	17	75	108	MWF	3	12	16
4	38mm	45	ROTOR	2.8/4.0	34	0.48	YES	NORTH	CLAY LOAM	153	MWF	3	17	75	108	MWF	3	12	16

Figure 10. Irrigation Schedule Chart

How Do You Do It?

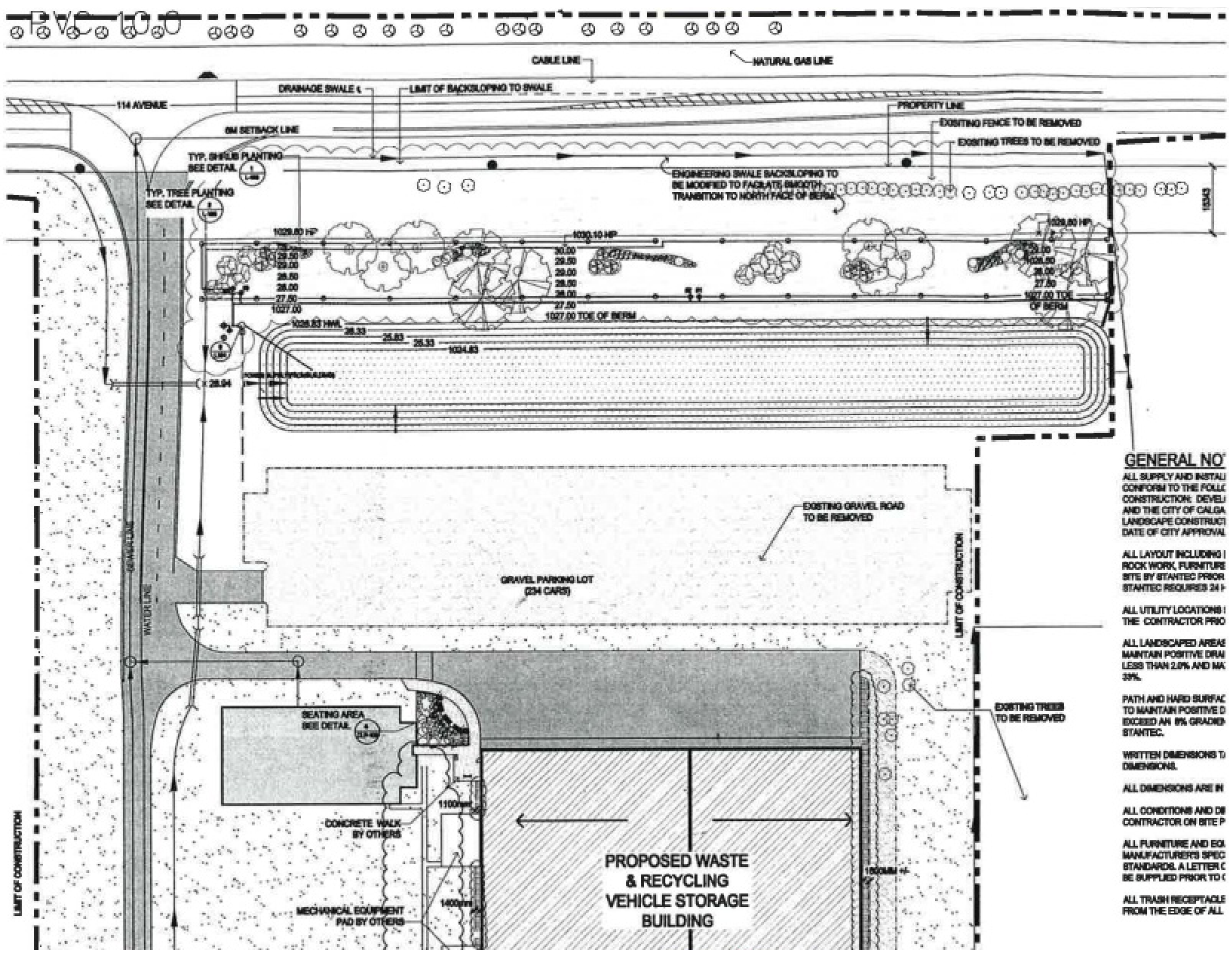

Figure 11. L.I.D.

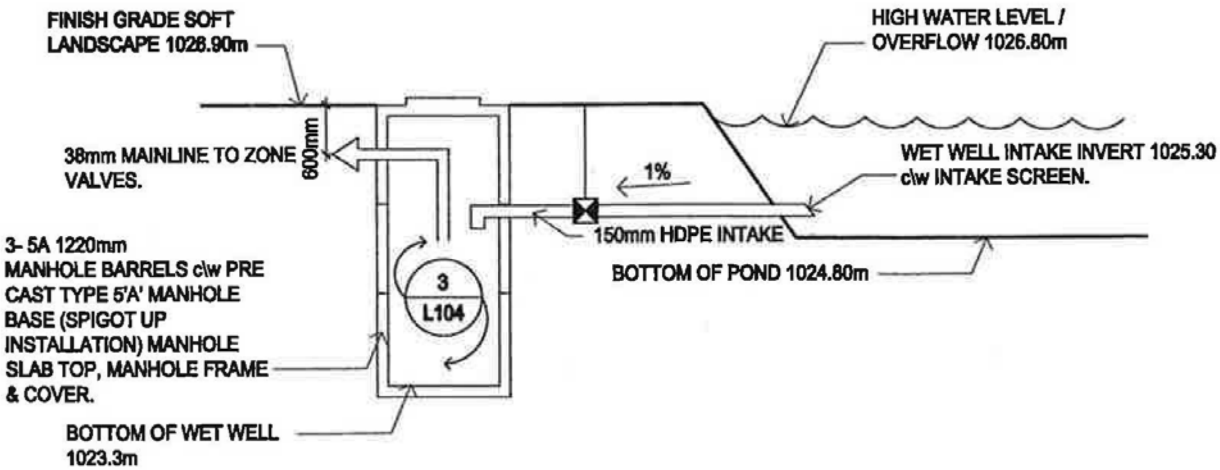

Figure 12. L.I.D.

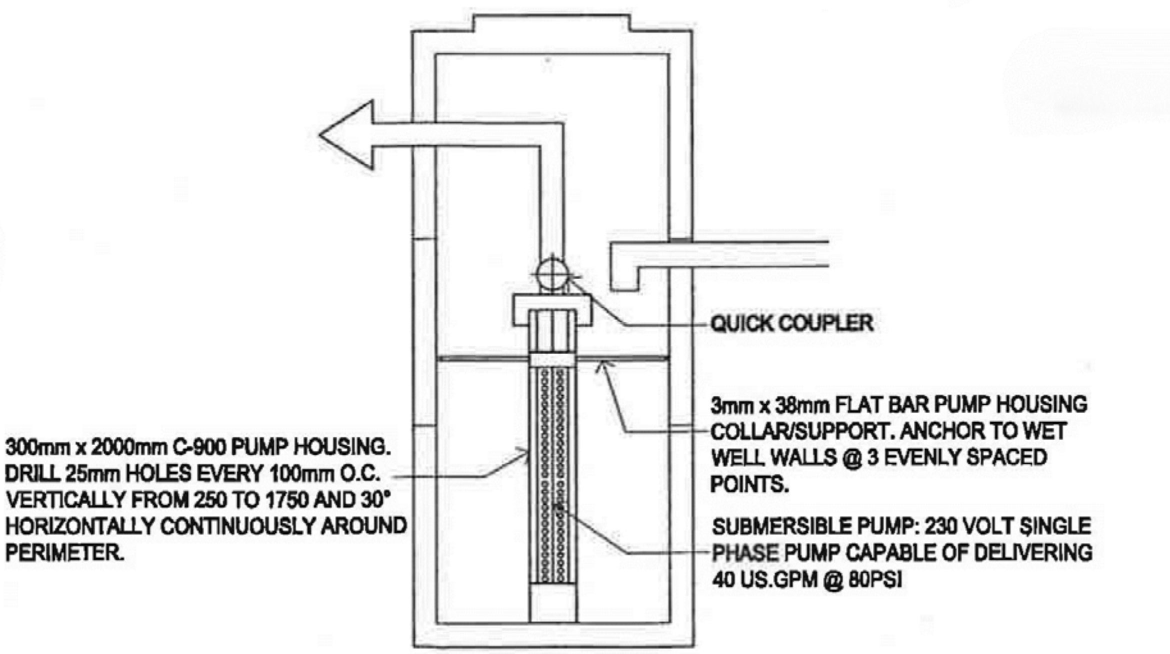

Figure 13. L.I.D.

Rainwater Harvesting

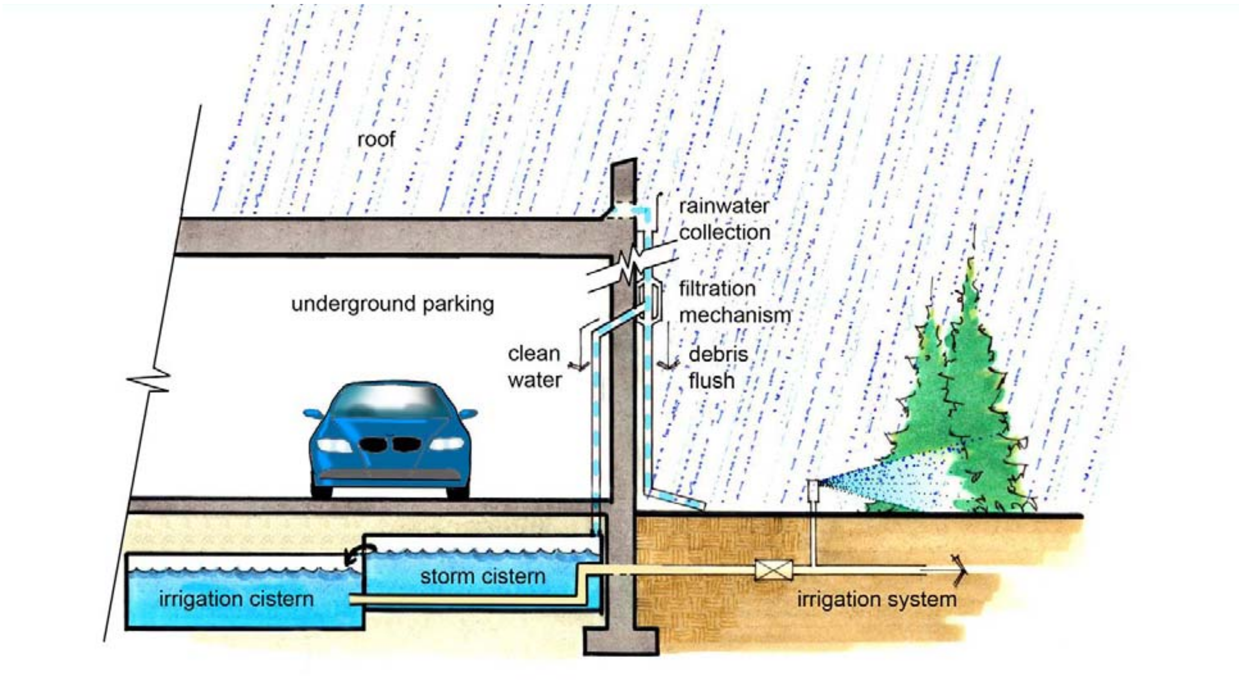

Figure 14. Rain Water Harvesting For Non-potable Use: Irrigation

Table 4. Non Potable Water Source Availability Calculation

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Irrigation Needs During Growing Season -64.64 m^3
Irrigation Needs Provided by Cistern 17.66 m^3

% of Irrigation Needs Provided by Cistern -0.27 m^3

Available Irrigation Water: A/W = TCA x CE x P x DWG = HW/M – DD = US Gal/m^3/month

Where:AIW = Available Irrigation water
TCA = Total Capture Area
CE = Capture Efficiency
P = Precipitation
DWG = Dewatering Water Generated
HW/M = Harvested Water per Month
DD = Draw Down

Conclusion

1) Irrigation Water Conservation: through a more interactive landscape/irrigation design process which gives consideration to plant species water use/requirements as an integral part of the landscape design species selection process.
2) Quantify Plant Water Requirements based on plant species selection & climate specificity as the basis of irrigation design: high water use species versus low water use or drought tolerant species.
3) Utilization of Non-Potable Irrigation Water Sources: improve LEED performance & increase compatibility with Low Impact Development principles.

References

Article in Serial Publication

"Water futures depend on what society chooses" (Dr. Howard Wheaton, 2013)

"The world is facing a crisis in water instability and is just walking up to the idea" (Dr. Howard Wheaton, 2013)

Conference, Symposium, or Workshop Proceedings and Transactions

"GEO 2000," the United Nations Environment Program UNEP