4.0 DESIGN GUIDE

Agricultural drainage may be viewed as a continuum of improvements from natural through surface, subsurface, controlled drainage and closely spaced tile systems for enhanced drainage and subirrigation. **Phased implementation may be undertaken in accordance with an overall drainage plan and the farmer's yield management objectives – low, moderate or high.**

Excess water on a field causes a reduction in soil strength reducing support and traction to farming equipment for planting, fertilizer and pesticide application and harvesting, all of which play a timely role in the quantity and quality of a crop (Fausey, 2003). Farmers are already decreasing drain spacing to support No Till, early planting and extended harvest season.

4.1 Planning

The first and most critical step in CDSI implementation is to review the Drainage Guide for Ontario (2007), CDSI Guide supplements, related CDSI web site content together with County soils mapping and related reference documents. Does your farm or a part thereof generally meet the key criteria for controlled drainage implementation? Important questions include:

Is there presence of an impermeable horizon no deeper than 1 to 2 m and the ability of the soils to support a water table as demonstrated by a perched water table conditions during part or all of the year?

Are your fields level with smooth slopes preferably less than 0.25% slope to minimize the number of water level control devices required in the main drain.

Do pond excavations on your property hold water levels year round?

Do you want to achieve low, moderate or high crop yields?

Do you wish to add a storage pond and subirrigation to your controlled drainage system?

Remember that soils and CDSI potential maps prepared at Provincial and County scales may not be accurate at field scales. A satisfactory drainage outlet will be required. A supplementary water supply for subirrigation will be necessary. Most farms will have to rely on collection of surface and subsurface drainage from crop lands for subirrigation water supply. This means a pond site will be necessary. Access to permanent or portable power for pumping to the subirrigation system will be required. The pond site may consume valuable crop production lands.

You may also wish to have preliminary discussions with Land Improvement Contractors, Drainage Consultants and experienced farmers. If you are satisfied you wish to proceed further, investment in a farm plan will be essential. This plan will include the following components.

4.1.1 Geodetic Control

It is essential that vertical and horizontal control be in the same Global Positioning System 'GPS' survey reference coordinate as used for guidance of farm and drainage equipment. Horizontal control should be referenced to standard provincial geographic coordinate systems including Latitude and Longitude.

Permanent elevation bench marks should be established on stable features adjacent to your farm fields. These benchmarks should be tied into the geodetic elevation network available on municipal road bridges and elsewhere in local municipalities.

4.1.2 Orthophoto Base

High resolution digital orthophotos (2002 to 2006) at this date are available for all of South Western and Central Ontario east to the Hastings County boundary and north to the Muskoka District boundary. Much of Eastern Ontario is scheduled for orthophoto coverage by Ontario Ministry of Natural Resources in 2008. These orthophotos are geographically referenced to provincial coordinate systems compatible with farm GPS guidance technology. They make an excellent base map for farm plans.

4.1.3 Rain Gauge

A rain gauge should be set up and growing season precipitation monitored. Pan evaporation monitoring will also be useful.

4.1.4 Observation Wells

Observation wells (mini piezometers) should be installed between existing subsurface drains and the water table depth monitored through the planting and growing season.

4.1.5 Yield Monitoring

Capabilities for yield monitoring on the basis of management treatment areas need to be established for existing conditions. This may require additional separate transport, weighing and storage facilities or capture of real time digital readouts from harvesting equipment.

4.1.6 Back Hoe / Auger Survey

During a dry period late in the growing season, a visual inspection of soil profiles and crop rooting depths should be undertaken by back hoe or hand excavation for the various soil landscapes on your farm. Inspections should extend to the top of the impermeable layer.

At a time of high water tables, auger holes should also be installed to 60 to 90 cm depth. After water levels have stabilized near the top of the hole, the water should be pumped out and the rate of water level recovery in the bottom 25% of the hole observed to assess saturated hydraulic conductivity. More details are provided in USDA (2001). Permeameters (Guelph) may also be used but secondary conductivity may be underestimated. It is very important that you know your soil / crop production environment.

4.1.7 Detailed Soils Map

A large scale soil map should be prepared on the digital orthophoto base for your farm including non farmed areas. Mapping should follow the legends of provincial soils maps. However don't rely on small scale mapping boundaries on documents prepared by others. This is your farm, your productive soil and your investment.

4.1.8 Topographic Field Survey

A detailed topographic field survey should be prepared preferably in digital format to facilitate design and drainage installation. This survey should be undertaken on a grid basis with breaklines at changes in slope and spot elevations on tops of knolls, in depressions and along the inverts of all perimeter ditches. Vertical elevation accuracy should be less than one half of drain tubing diameter (say 50 mm). Remember that this plan will form the basis for design and guidance of machines installing subsurface drainage tubing. Errors or omissions in the mapping will show up as future yield reducing dry knolls, wet depressions, poorly functioning drains or other operational deficiencies which will slow planting and harvesting and be more difficult to correct.

4.1.9 Existing Drainage Infrastructure Map

A detailed map illustrating existing surface and subsurface drainage is required. The orthophotos and historic aerial photography may be of assistance in location of existing drains. However selected excavations may be necessary to confirm the location and grade of the existing drain runs. Remember decisions will have to be taken during design about whether to blind and abandon existing drains or to retrofit into the new CDSI design.

4.2 Water Level Design

4.2.1 Water Level Elevation Control Zones

The fields proposed for CDSI treatment should be divided into elevation zones for water level control. For cash crops such as corn and soybeans current standard practice is to use 30 cm elevation intervals. However for shallow rooted vegetable and specialty crops, 15 cm elevation zones may be required. Zones may have to be adjusted to ensure depressions and knolls are adequately treated. Utilization of more restricted vertical zones increases soil water storage and may be necessary for southwestern Ontario's shallow tile systems (60 cm).

For a standard 100 acre farm with 120 rod frontage and 133 rod (670 m) depth and assuming a uniform 0.5% slope of the drainage main, the grade fall (rise) would be 335 cm over the 670 m length. In this example, eleven 30 cm water level elevation control zones would be required.

4.2.2 Water Table Design Depth

The depth of root growth is strongly affected by the water table, thus the risk of flooding and damaging a crop from a rainfall event is more likely for lands whose water tables are close to the surface. Design water table depths may be as high as 25 cm over the drains and 45 cm at the sags for fine textured soils (Brookston clay loam soils). Design depths may be deeper on fine sandy loam and S3 Group Soils with greater permeability and upward moisture flux. Controlled drainage may reduce yields if drainage controls are not removed and replaced in a timely fashion when heavy rainfall is imminent.

4.2.3 Existing Drainage Retrofit

A decision may be taken to consider retrofitting controlled drainage subirrigation to an existing conventional subsurface drainage system. For retrofit to existing wide spaced tile systems, closely space tile systems may be achieved by splitting the runs and in some cases inserting two runs between existing drain runs. New distribution mains intersecting the tile runs will be required to create appropriate elevation zones. Retrofitting may result in a greater length of main, shorter laterals and less control over water tables in comparison to a purpose built system.

4.3 Drain Depth, Grade and Diameter

4.3.1 Depth

The practice in Northwestern Ohio and in Eastern Ontario is to place subsurface drainage at 90 to 100 cm depth, whereas in Southwestern Ontario the practice is to install drains at 60 cm depth in fine textured soils.

Deeper drain installation may increase the water storage capacity of the soil profile. However shallow closely spaced tiles provide better water table control than deep widely spaced tiles. Consideration should also be given to placing tubing at the depth of greatest lateral hydraulic conductivity in the soil profile.

Drains must be placed at a minimum 60 cm depth for protection from soil cultivation and crushing under heavy surface loads. For Ontario conditions tubing should be installed at the minimum 60 cm in soils with fine textured parent materials (S1 and S2). The Ontario Drainage Guide (2007) advises that for conventional free drainage lateral drains should not be installed deeper than 75 cm for coarse sandy soils. However for controlled drainage on coarser textured soils over fine textured impermeable layers (S3), drain tubing may be installed deeper (90 cm) towards the interface of the lower impermeable layer and wider drain spacing employed.

4.3.2 Grade

Ability to flush lateral and main drains may be required as new laterals may have to be installed at very low gradients or level. Pooling in the tubing may lead to sedimentation where soil erosion and turbidity is prevalent due to poor soil management practices. Fields should be managed for clear water infiltration into the tubing. Direct inlets for surface drainage are not recommended. Granular envelopes and filter media may be required in some soils to prevent siltation.

Uniform lateral grades at 0.025% or lower are recommended for controlled drainage and subirrigation. These grades are below the lower limit specified by the Ontario Drainage Guide (2007) for conventional free drainage for standard 100 mm diameter corrugated and smooth wall tubing. For cash crops a maximum tubing length across a standard 120 rod farm frontage, the length would be about 2000 ft (600 m) and the elevation rise of the tubing upgradient of the main would be 15 cm. At 6 m lateral spacing the drainage area would be 0.36 ha. Fig 2 in the Ontario Drainage Guide (2007) confirms that for this length, 100 mm diameter corrugated plastic drainage tubing will provide a drainage coefficient in excess of 12 mm/day. However this coefficient may not be sufficient for controlled drainage water levels. More closely spaced drains of this length would be required for specialty crops. With closer spacing the drainage coefficient will increase for the same length and diameter of tubing.

4.3.3 Drain Diameter

Standard 100 mm tubing diameter is recommended for laterals due to the need for increased drainage coefficients for lower grade installments.

4.3.4 Drainage Coefficients

Drainage coefficients must still be calculated in accordance with the Ontario Drainage Guide 2007. Drainage coefficients should be increased to provide for more rapid drainage when the water table is maintained at a higher level.

4.3.5 Land Smoothing and Shaping

Special attention must be paid to drainage of field depressions. Occasionally land shaping may be required to improve drainage. Reservoir excavation may provide a source of material for shaping however soil profile and top soil restoration difficulties should not be underestimated where subsoil materials are utilized for shaping.

4.4 Drain Horizontal Alignment and Spacing

4.4.1 Horizontal Alignment

For controlled drainage and subirrigation, lateral drains should follow the direction of minimal land slope and mains the general direction of greatest surface slope. This will provide the most efficient main sizing and also permit progressive introduction of inline (level) control devices for more precise water level control. Frequent access will be required along the main drain for visual inspection of water level control devices and irrigation water inputs. Consideration may be given to design of the main drain as a partially open tube channel through the water level control sections with vertical flash boards for water level control.

Lateral drain horizontal alignment will likely be curvilinear and follow the ground surface contour to provide a minimum of 60 cm cover. Drain spacing will be subparallel if curvilinear and spacing may vary. Cover at the down gradient tubing entrance / exit would be a minimum 60 cm plus the grade rise for the lateral. Subirrigation will likely be at a maximum equivalent evapotranspiration flow rate of about 5 mm day. The subirrigation peak flow rate is substantially lower than drainage mode operation flows. However subirrigation flows will be continuous over extended periods during the summer growing season. Drain head losses during subirrigation operational mode have not been reported by current research.

Controlled drainage installation and preparation of 'as built' farm drainage maps will be facilitated by utilization of GPS guidance and laser depth control for precise installation of laterals.

4.4.2 Drain Spacing Guide

Subirrigation systems require more closely spaced drainage tiles than free draining conventional tile systems. There is already a trend to closer conventional drainage spacing in Ontario.

Table 3 in the Ontario Drainage Guide (2007) provides recommended spacing for conventional subsurface (free) drainage by Drainage Design Code Soil Groups. Drainage Guide recommended spacings for cash crops range from 6 to 15 m. Closer minimum spacing is recommended for some specialty crops (Table 4 includes drain spacing for specialty crops including vegetables on mineral soil (4.5 to 6 m) and grapes (2.5 to 3 m). Table 1 of the Guide provides recommended lateral drain spacing based on soil texture as percent of the recommended spacing in Table 3. This spacing varies from 45% for silt, 70% for loam and silty clay loam, 80% for sandy loam to 90% for loamy sand. Drainage performance and the secondary hydraulic conductivity especially on soils not previously drained is also known to improve over time.

The Drainage Guide for Ontario (2007) recommends shallow and narrow spacing vs. deeper and wider spacing. Shallow and narrower spacing achieves optimal root zone conditions in a shorter period of time with less total removal of water volume. The Guide recommends avoiding drainage of shallow muck soils 450 mm or less in depth, over sand and impermeable clay. Installation of subsurface drains is also not often advised in marl or in shallow soils over bedrock. Heavy clay soils may be considered impervious and unsuitable for subsurface drainage installation. However management may improve the drainage of these soils.

Table 2 of the The Drainage Guide for Ontario (2007) provides a listing of Ontario Soil Series and Related Drainage Design Codes for conventional free drainage. This Table, through consultation with OMAFRA, has been used to prepare an initial approximation of soil capability for controlled drainage subirrigation. **The Soil Groups S3 and S5 have been classified as 'Good'; Groups S1, S2 and S4 as 'Fair' and Groups G1, G2, G3 and S6 as 'Poor' for CDSI without regard to natural drainage or slope.**

The following controlled drainage subirrigation spacing is currently proposed as a Guide for high yield management and high soil trafficability based on the Ontario Drainage Guide (2007) Design Code Soil Groups (Table 2) and ongoing CDSI research experience. **Management for low or moderate yields may adapt wider spacings and delete subirrigation and storage ponds. Proposed spacing will be adjusted as additional field experience may be integrated.**

- **S1 Drain spacing at 2 m for specialty crops and 4 m for cash crops** on fine textured and heavy clay soils. **Drains at 60 cm depth.**

- **S2 Drain spacing at 3 m for specialty crops and 6 m for cash crops. Drains at 60 cm depth.**

- **S3 Drain spacing at 4 m for specialty crops and 8 m for cash crops. Drains at 90 cm depth.** Where surface soils are sandy and lateral hydraulic conductivity is high, drain spacing may be increased. However where surface soils are fine textured, closer spacing similar to S2 may be required.

- S4 soils have not been identified in Southern Ontario Counties.

- S5 soils require special case by case design evaluations.

- S6 soils require special case by case design evaluations.

- **However some G1 soils may be similar to S3 soils in that the seasonal water table is perched on the 'C' horizon. Recommendations for drain spacing and depth are similar to S3.**

- **It may not be possible to maintain a water table on some S3 and G1 soils and CDSI therefore will not be feasible.**

- G2 and G3 are not recommended for CDSI due to absence of shallow impermeable layers and connection to regional groundwater systems.

- **The recommended drain spacing should be adjusted closer for poorly managed soils or soils not previously drained. Drain spacing may be increased 1 to 2 m for well managed soils.**

- Retrofitting to existing subsurface drainage systems will likely require compromises in drain spacing and length.

- Retrofitting of existing subsurface drainage systems with controlled drainage will produce moderate yield benefits at lower costs.

The final design spacing must consider the unique field site characteristics, local drainage practices and crop yield management objectives and experience.

4.5 Water Level Control Devices

There are a variety of different water level control devices available from manufacturers as well as custom made devices. Water level control devices must be leak proof and able to **control water levels to as high as 15 cm below ground level at the control device. The device should be capable of lowering water levels in 10 cm increments to below the lateral drain inverts.** Maintaining seasonally uniform water levels at the control device is important due to difficulties of rewetting the soil profile if water tables fall below optimum levels. The device should permit rapid visual water level inspection from the surface.

The water table control devices must be easily opened to permit operation in free drainage mode as required.

4.6 Storage Pond (Reservoir)

The storage pond is an essential component of a seasonally 'closed loop' Conservation Drainage System, but is not required for Controlled Drainage alone. The pond collects overflow water from the controlled drainage system and provides a supply of water for recycling and crop subirrigation through the subsurface drainage system. The pond provides water quality improvements for drainage water released from the site. It may also be a source of fire protection water.

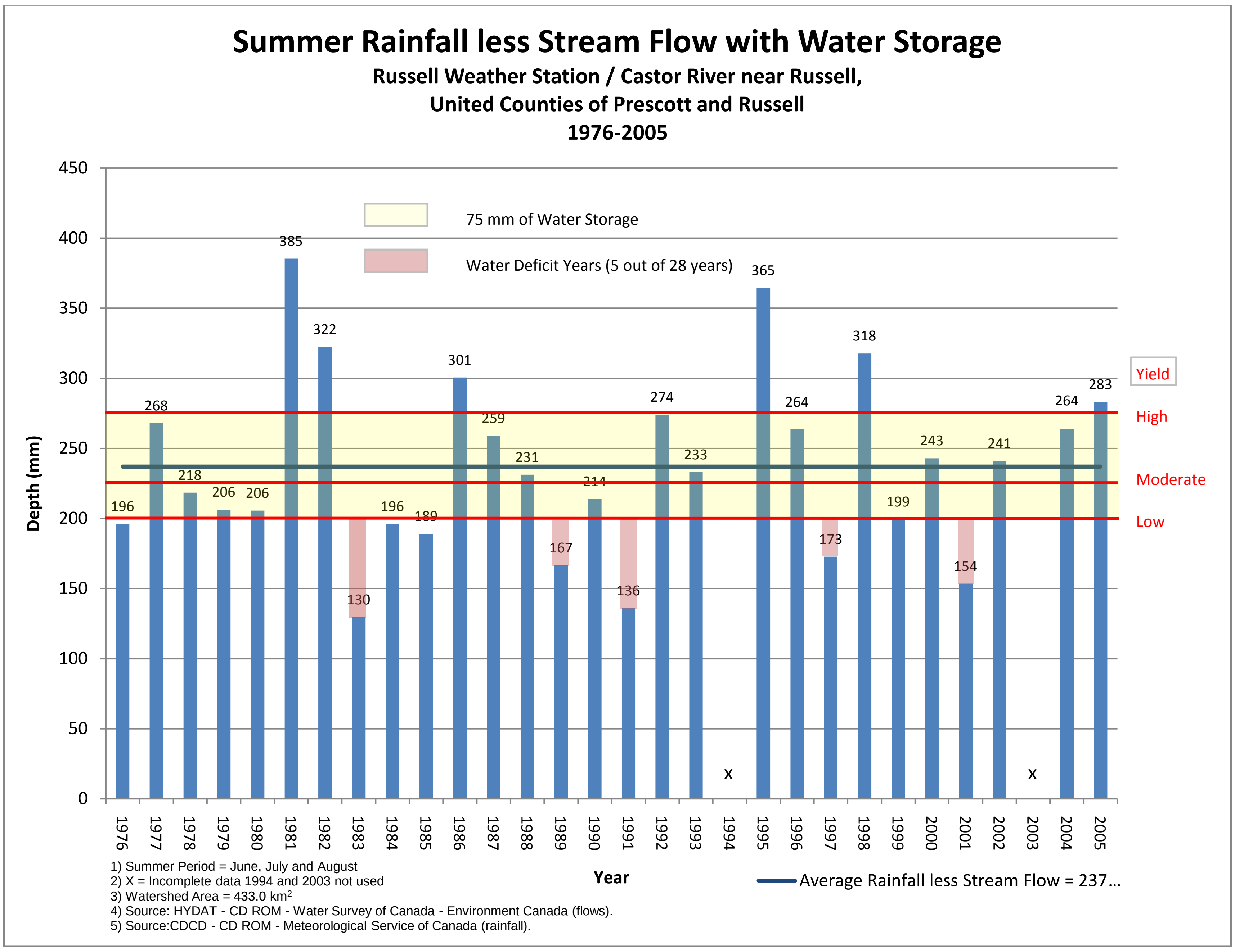
- Storage ponds may be located near the low point of the crop lands to facilitate filling by gravity from the field drainage system and minimizing seepage losses.

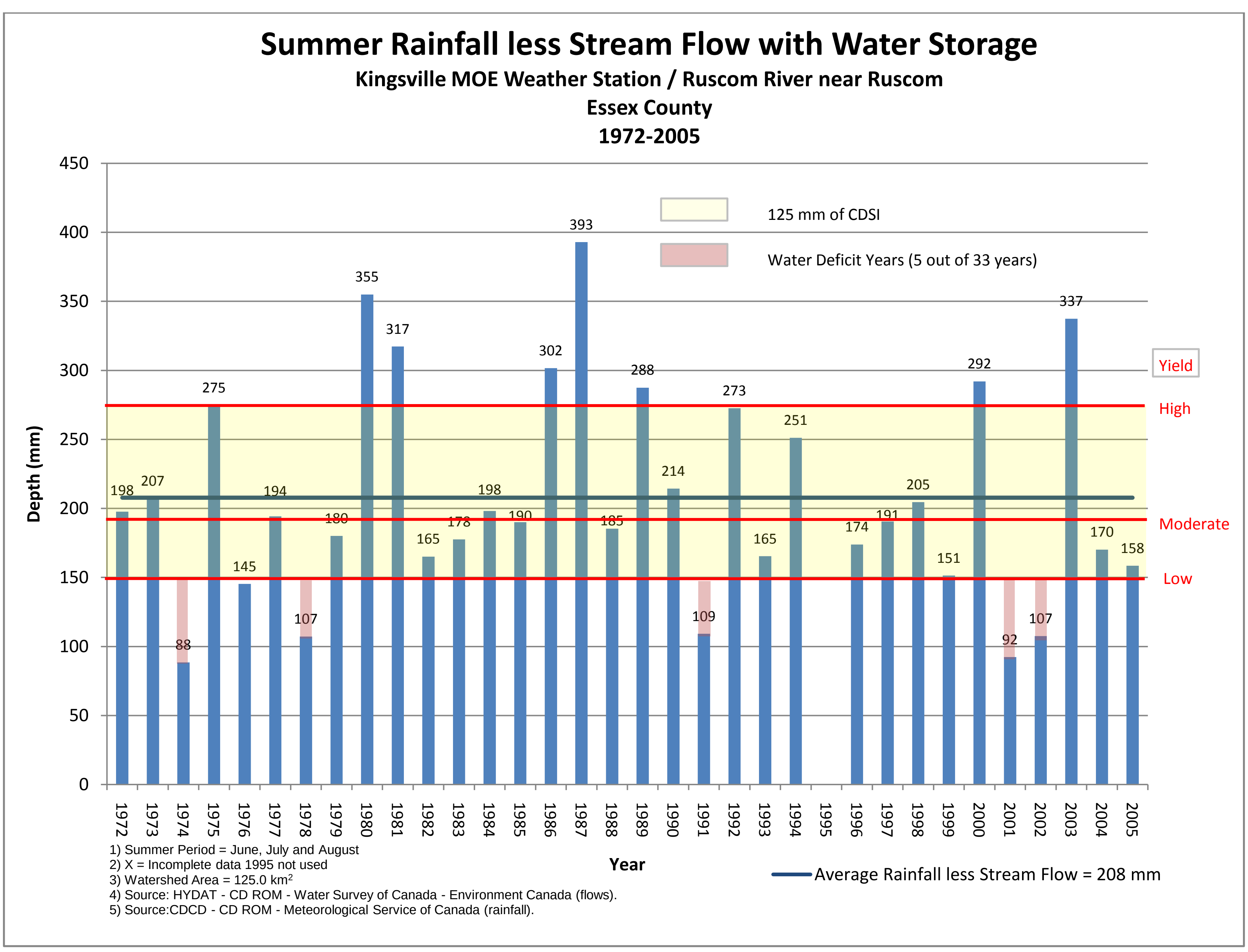
- Ponds should have good year round access with an electrical supply for extended period low flow pumping to subirrigation drainage control weirs.

- The pond may be designed to store spring runoff equivalent to the average summer water deficit (potential minus actual evapotranspiration) which is 100 to 150 mm on average in Southwestern Ontario (C. Tan, pers. comm. July 2007).

- However excavation of a water table pond of this volume will be expensive and require considerable space (2 to 3 hectares or more) not including spoil disposal. On some farms in more undulating terrain there may be natural impoundment sites allowing reduction of excavation quantities.

- The storage pond should be **sized to meet the water deficit and subirrigation demands for 8 years out of 10 or a minimum of about 275 mm of combined summer precipitation (June, July, August) and stored water. This corresponds to about 75 mm of water storage in Eastern Ontario and 125 mm of water storage in Southwestern Ontario.** Part of this storage will be in the soil achieved via controlled drainage and the remainder must be made up from reservoir storage of snowmelt and early spring rains (Fig 4.1).





In these plots, summer stream flow has been subtracted from the summer precipitation. Water storage requirements have been based on approximately 2 wet years and 2 drought years in each decade. This analysis indicates 100 mm of pond and soil storage is required in Eastern Ontario and 125 mm pond and soil storage in Southwestern Ontario to supplement rainfall.

Fig. 4.1

- Through effective water management including higher water tables at planting, early planting to permit restoration of controlled water levels from early season (May) rainfall, capture of summer storm runoff and a crop rotation strategy with irrigation of only highest value crops during extreme drought years, **the pond size may be reduced to roughly 100 mm in Southwestern Ontario and 50 mm in Eastern Ontario on fine textured impervious soils.**

- Partial above ground pond construction with embankments constructed from excavated spoil will increase management time and costs for pumped pond filling, result in increased seepage losses and require a greater land area.

- No allowance for pond evaporation and leakage and/or drain seepage and leakage is included in the above estimates. Larger ponds will be required where field leakage and seepage is significant.

- Larger pond sizes will provide greater protection against draught but at diminishing economic returns. Area for future pond expansion should be considered.

- However for 2 out of 10 years minimal pond storage will be required due to excess summer rainfall.

4.7 Design Example

Conservation drainage design concepts for a new or replacement controlled drainage subirrigation system and phased existing drain retrofit for a typical farm on Brookston clay loam soils have been included in attached Drawings 1 to 4. Drawings 5 and 6 illustrate plan and cross section views for in ground and partially above ground storage ponds.

The storage pond has been sized on this concept to provide 75 mm over the entire drained area (90 acres) or 150 mm over 50% of the drained lands considering crop rotation strategy and irrigation of only highest value crops during severe drought years. The design must have flexibility to permit management for a variety of climate and cropping scenarios. Cropping patterns may need to be adapted to the control drainage-subirrigation zones.

Pond volume to store 75 mm not including losses to evaporation would need to be about 25 acre ft or about a 3 acre surface area including a buffer with maximum 13 ft pond depth to provide subirrigation water supply for a typical 100 acre farm with 90 acres under cultivation (e.g. 45 acres corn and 45 acres soybean).

A 75 mm pond volume would require excavating about 45,000 cubic yards of material in level ground assuming a 1 foot freeboard. Spoil from the excavation would have to be used in land grading, exported from the site or alternatively additional embankment storage area provided.

4.8 Agency Approvals and Permits

Chapter 1 in The Ontario Drainage Guide (2007) provides an outline of the approvals and permits that may be required to proceed with a controlled drainage subirrigation implementation. The farm owner is responsible to obtain the necessary permits and approvals to proceed.

4.9 Contractor Responsibility

The land improvement contractor is responsible to the farm owner to ensure the controlled drainage system is competently designed and constructed to enable control of water levels within acceptable tolerances for the range of conditions to be anticipated and agreed upon with the farm owner.

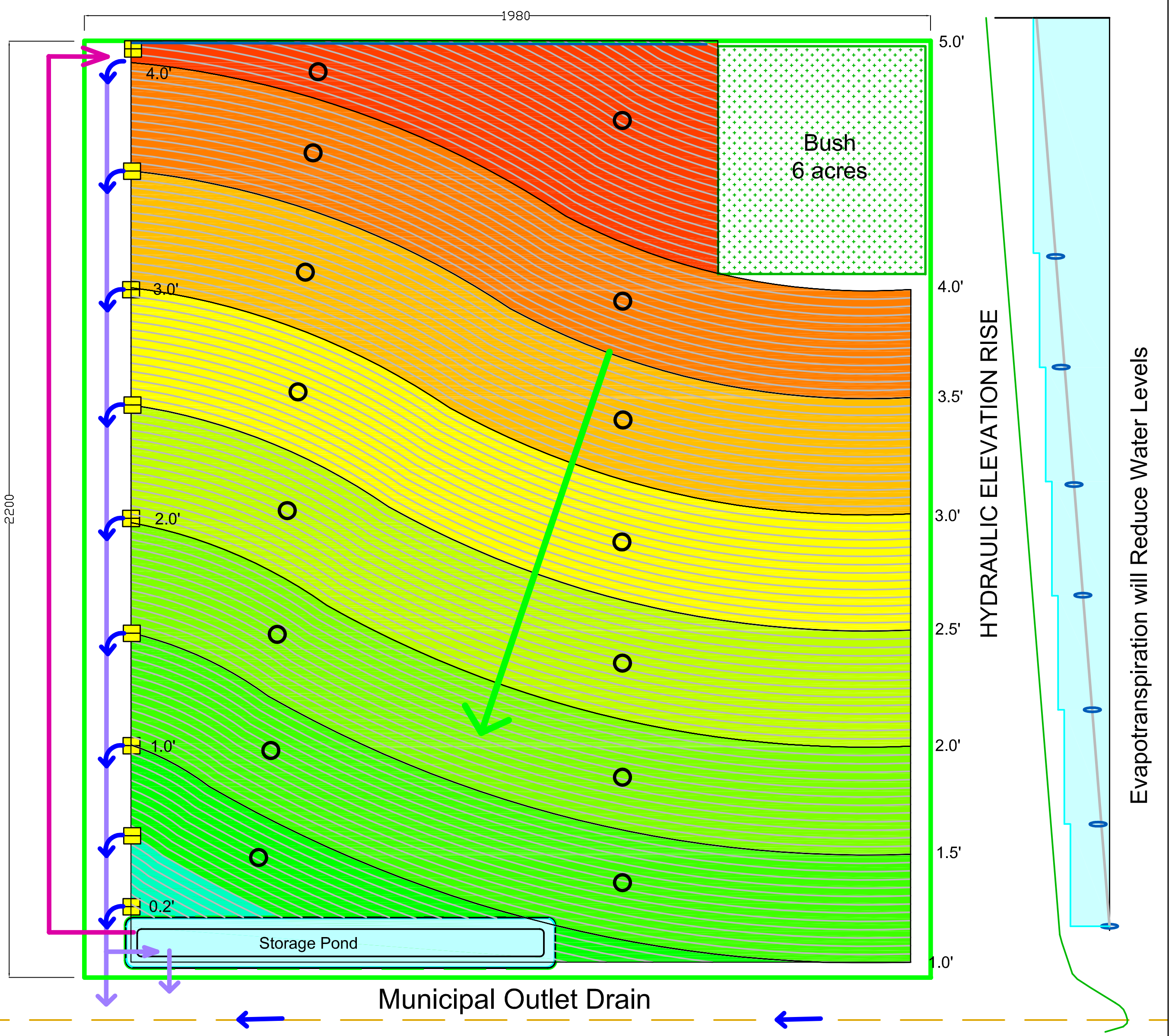
The contractor is responsible to provide the farm owner with a detailed ‘as built’ plan of the drainage system.

4.10 Farm Owner Responsibility

The farm owner is responsible for operation and management of water levels to optimize his crop production. This responsibility includes management during unusual rainfall events and drought conditions.

Dwg 1.0

New or Replacement CDSI with Closely Spaced Laterals and 6 Inch Elevation Control Zones and Storage Pond



LEGEND

New 4 in Laterals @ 20' spacing		Control Weir	
Subirrigation Header (Pumped)		Ground Surface	
Township Lot Line (100 acres)		Drainage Header	
Observation Well		Drainage Water Flow	
		Bypass Drain / Overflow	

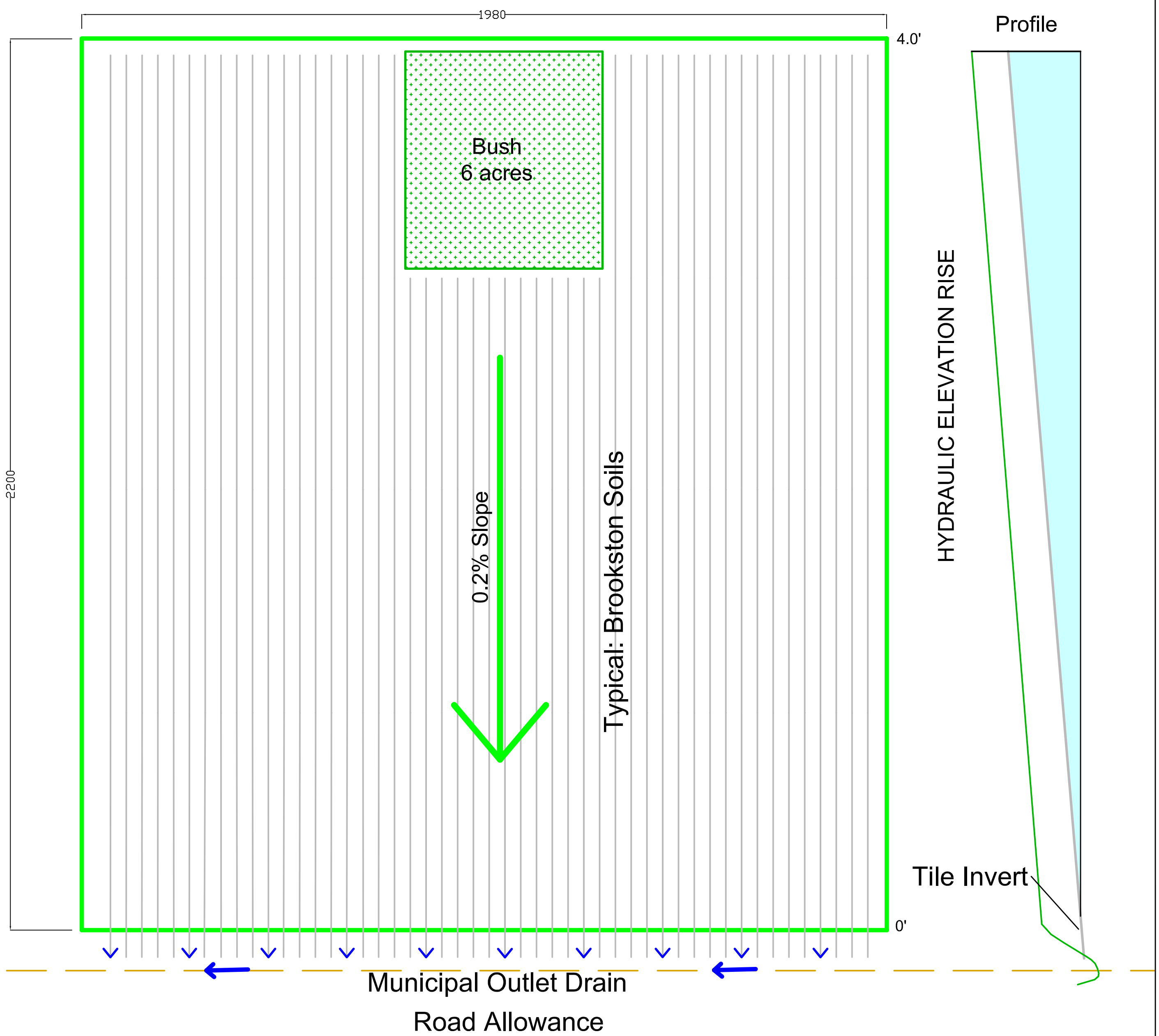
Plot Scale: H:1" = 400' V:1" = 20'
Plot Date : January 17, 2008

Concept

Funded in Part by Canada Ontario
HUNTER GIS

Existing Drained Field

(0.2% Grade on Brookston Soil)



LEGEND

Existing 4 in Laterals @ 40' spacing

Township Lot Line (100 acres)

Ground Surface

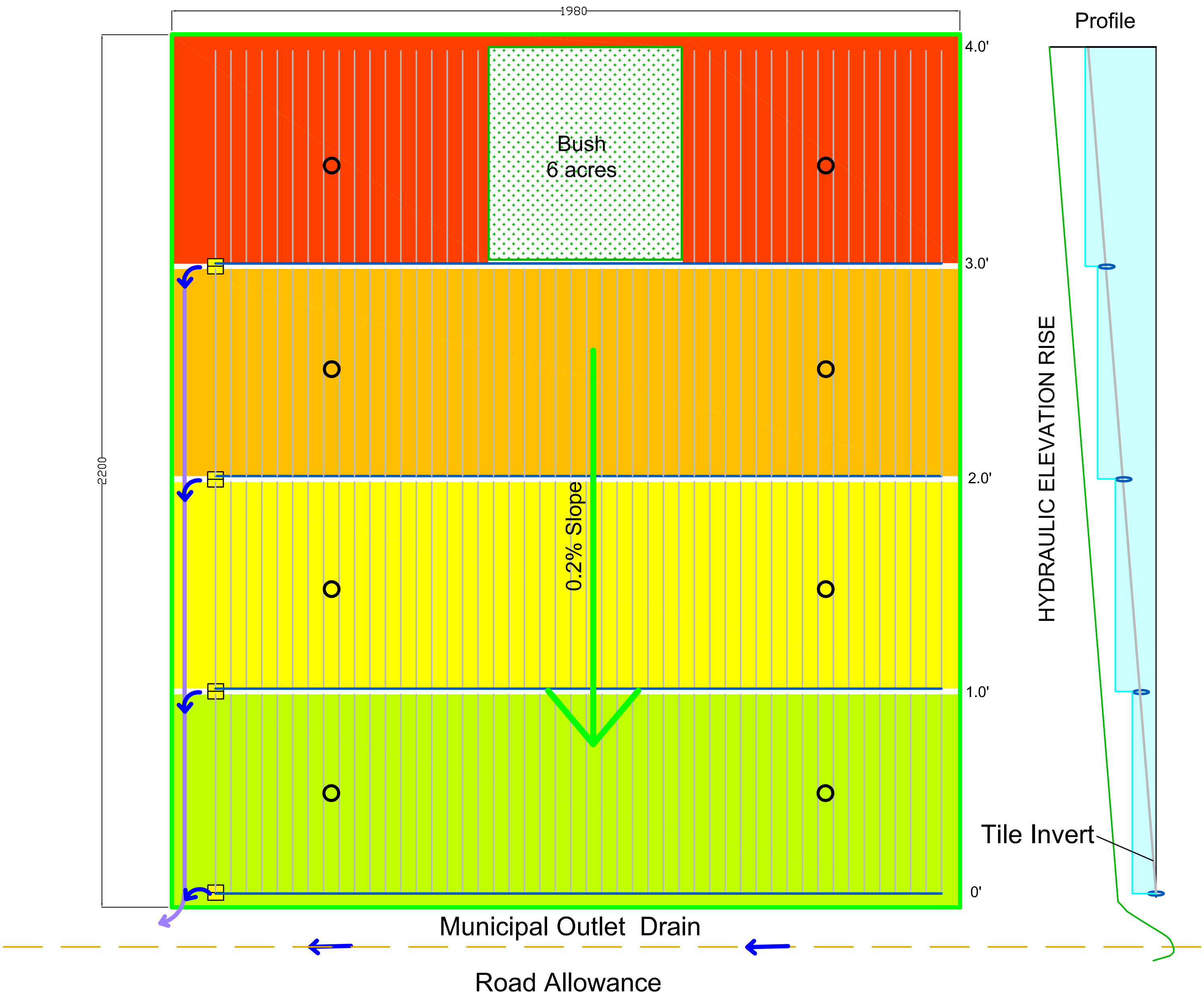
Drainage Water Flow

Plot Scale: H:1" = 400' V:1" = 20'
Plot Date : July 12, 2007

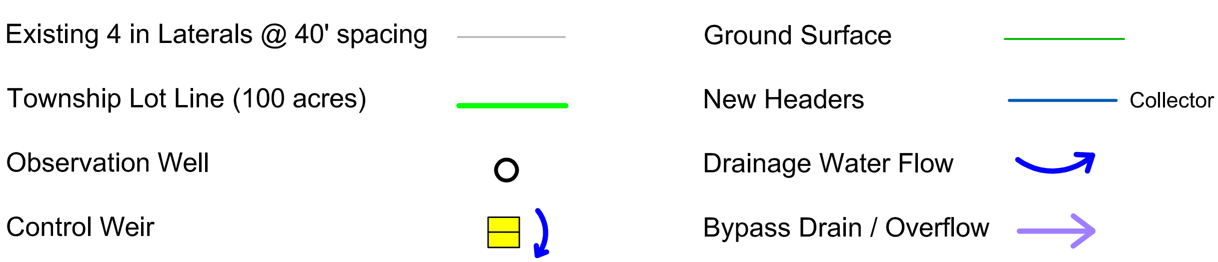
Concept

Funded in Part by Canada Ontario HUNTER GIS

Controlled Drainage Retrofit with 12 Inch Elevation Control Zones



LEGEND



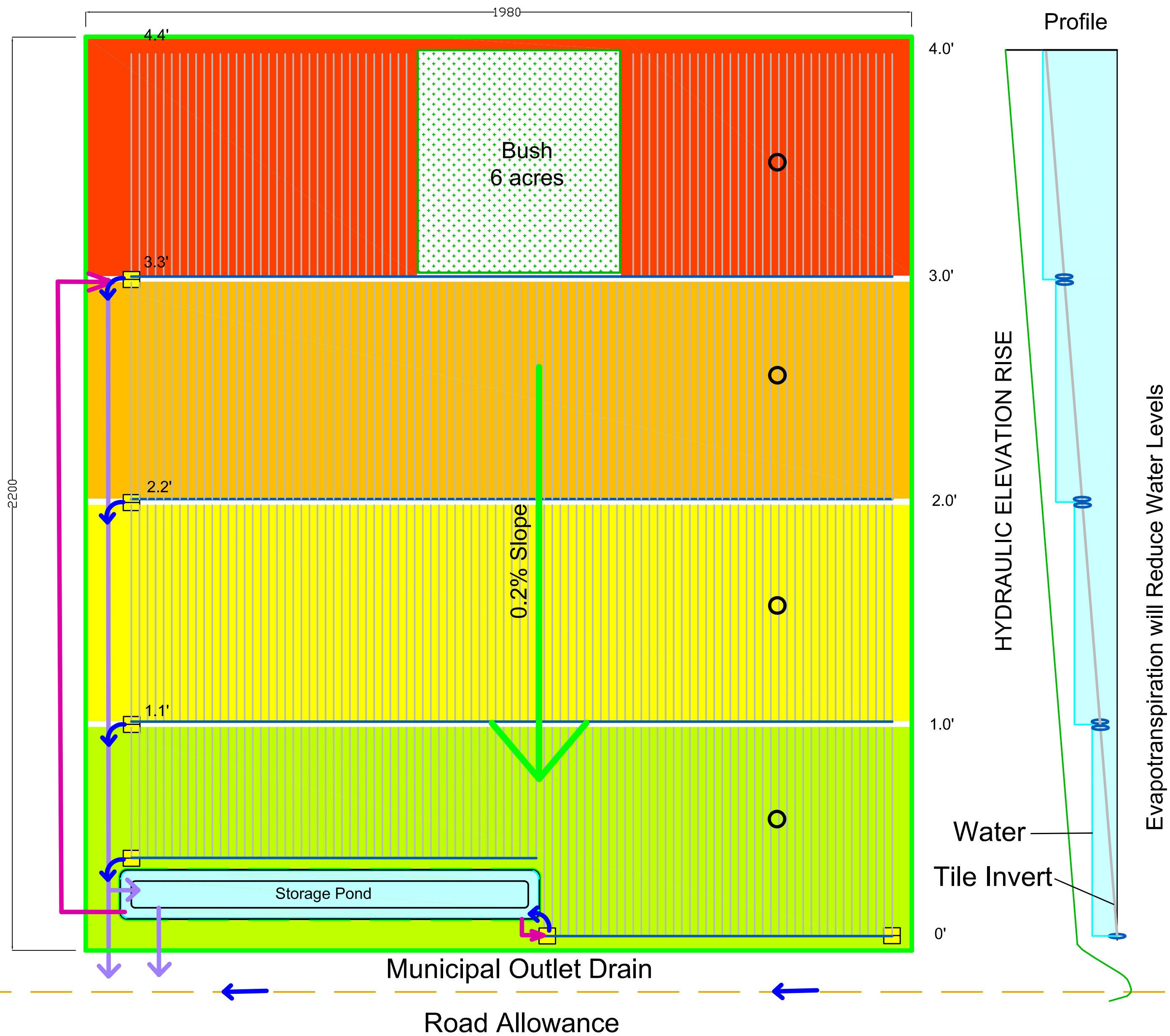
Plot Scale: H:1" = 400' V:1" = 20'
Plot Date : January 3, 2008

Concept

Funded in Part by Canada Ontario HUNTER GIS

Dwg 4.0

Retrofit with Storage Pond, Closely Spaced Tiles and Subirrigation



LEGEND

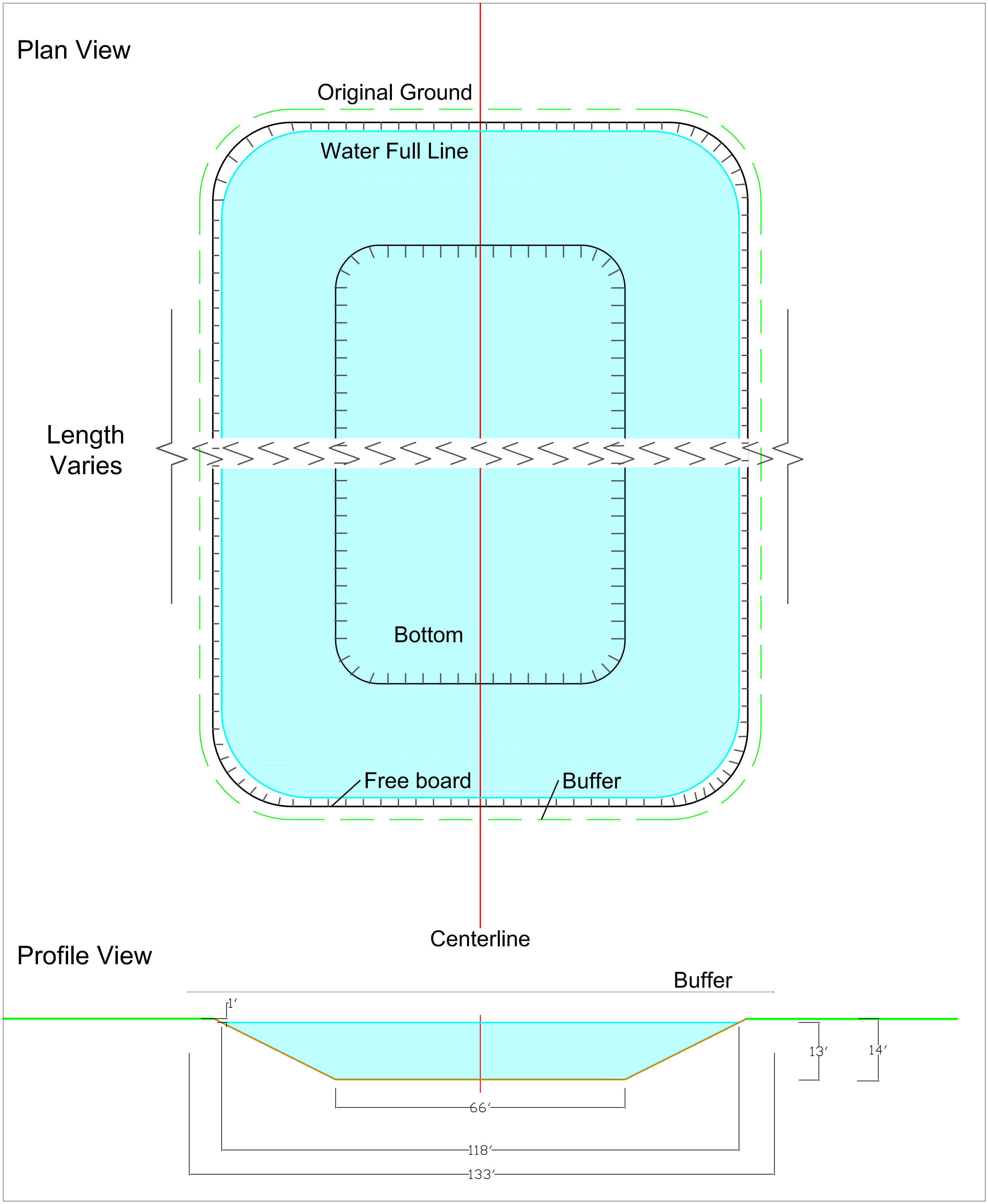
Plot Scale: H:1" = 400' V:1" = 20'
Plot Date : January 17, 2008

Concept

Funded in Part by Canada Ontario

HUNTER GIS

Storage Pond at Ground Level
Spoil to Land Levelling or Export

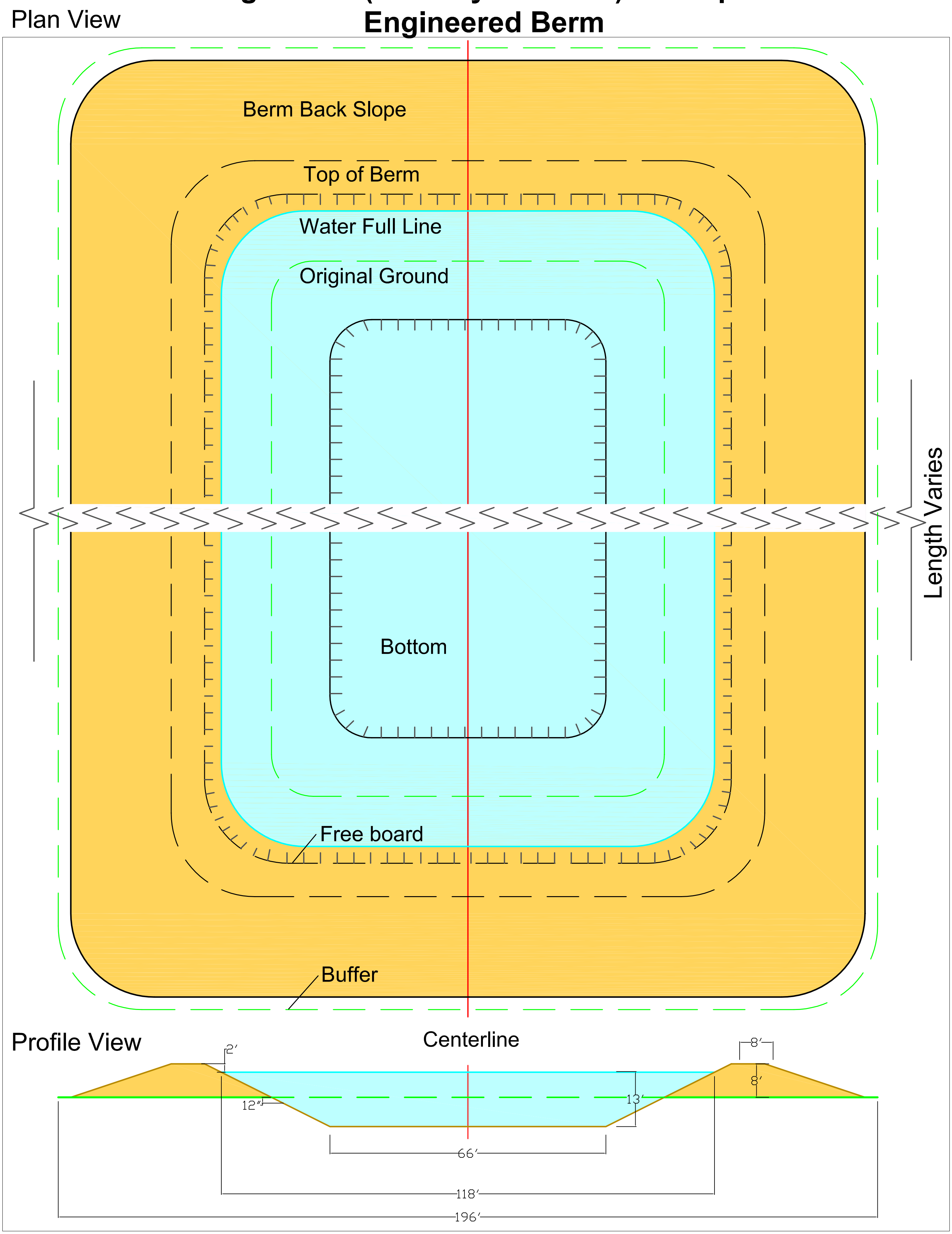


Plot Scale: 1" = 30'
Plot Date : January 17, 2008

Concept

Funded in Part by Canada Ontario

Storage Pond (Partially Elevated) with Spoil in Engineered Berm



Plot Scale: 1" = 30'
Plot Date : January 17, 2008

Concept

Funded in Part by Canada Ontario