

CI2170: BIM for Civil Engineers: Intelligent Hydraulics and Hydrology with Autodesk AutoCAD Civil 3D

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CI2170: BIM for Civil Engineers: Intelligent Hydraulics and Hydrology with Autodesk AutoCAD Civil 3D

Autodesk AutoCAD Civil 3D software gives us many great features out-of-the-box for our day-to-day hydraulics and hydrology (H&H) modeling needs, but it's not until you dig deeper that you find it can truly bring out the "I" in BIM for civil engineers. Stop limiting your H&H workflow inside of the Autodesk AutoCAD software environment to simple area takeoffs. Don't limit the pipe network functionality to what comes out-of-the-box. Learn to use Civil 3D pipe networks, parcels, and catchment objects to greatly improve H&H productivity and drainage map plan production. Empower your team with the tools needed for advanced H&H workflows in Civil 3D as the data is prepared for seamless exporting into the Hydraflow Storm Sewers Extension for Civil 3D or for Autodesk Storm and Sanitary Analysis software. This class focuses on setting up your drawing templates and shared part catalogs for enhanced H&H modeling. We do discuss workflows, but this class focuses mainly on setting up the tools that are needed to perform the workflows.

Key learning objectives

At the end of this class, you will be able to:

- Create dynamic labels and expressions for storm systems and hydrology catchment areas.
- Customize the part catalog shared parameters for enhanced information modeling and data entry.
- Customize parcel styles and user-defined properties for hydrology information modeling.
- Prepare standard or specialized drawing templates for a fully integrated hydrology and hydraulics workflow.



Let's put the "I" in BIM for Civil

PS Why isn't "CIM" a thing?

Site Development H&H Workflow Before Civil BIM

- 1) Create line work in CAD; single lines... doubles are way too much work.
- 2) Hand calculate and add text labels to plan sheets / Alternatively utilize Excel and CAD at the same time, jumping back and forth, to design with Excel doing the calculations for slope and inverts. Cover and rim elevations were usually an afterthought.
- 3) Create profile sheets (Very time consuming! Very rarely was completed, and the client paid extra for it. Was avoided when possible).
- 4) Add text labels to profile sheets
- 5) Create a Structure and Pipe chart in Excel. Data links were possible, but often not used due to reliability issues.
- 6) Copy and Paste data from Excel sheet to pipe chart and structure chart in CAD.
- 7) Delineate watersheds for catchments using areas. Add individual impervious and pervious area take-offs.
- 8) Hand calculate weighted C values.
- 9) Calculate $Q=CIA$ by hand or by Excel spreadsheet.
- 10) Re-enter all the exact same data into Hydraflow Storm

Sewers. **If HGLs weren't required, this step was often omitted. Flows were simply stacked Qs for inlet capture flow. This often resulted in oversized pipes.*

- 11) Optimize the design in Storm Sewers
- 12) Revise data in Excel tables
- 13) Revise line work in CAD files
- 14) Revise annotation in plan and profile.
- 15) Revise plan and profile (Very tedious for profiles!)
Forget about hatching cut and fill zones! FG and EG are rough approximations... Back to AVOID PROFILES AT ALL COSTS! If revisions are needed, ask the PM to start a Request for Additional Services Change Order.
- 16) Add HGLs to Profiles (Avoid when possible)
- 17) Re-copy and paste data from Excel to CAD.
- 18) Cross your fingers and hope you didn't miss anything; Avoid revisions at all costs!

***AVOID REVISIONS AT ALL COSTS**

Site Development H&H Workflow After Civil BIM

- 1) Create a Parts List (default in template is usually 90% or more complete)
 - 2) Layout network using standard labels and rule sets
 - *Initial sizing is estimated using “Design Information” labels in plan view.
 - **Grading is typically done before pipe networks when possible. Sometimes if it is known that outfall and pipe slopes will drive grading, pipes will be laid out first.
 - 3) Create profiles in C3D for optimizing vertical layout and crossings (crossings are no longer an afterthought).
 - 4) Annotate plan and profile sheets using standard label styles (in template).
 - 5) Delineate catchment areas using new parcels and Catchment object workflows; link catchments to pipe network.
 - 6) Export pipe network (with linked catchment information) to Storm Sewers. Add bypass links and gutter slope values as-needed.
 - 7) Import optimized design back to C3D. Cleanup Storm Sewers to C3D short-fallings (some pipes disconnect). Must make sure Parts List is all-inclusive.
 - 8) Create Pipe and Structure Tables using the one-button push for each.
 - 9) ... That’s it... We’re done.... This is not really a step, but we’ll use it as a catch-all for fixing C3D quirks or making minor adjustments to structure rotation, part sizes, etc.
- * Revisions... Not a problem. The annotation is done, the profiles update themselves, grading updates the rim elevations, and round-tripping to-from HSS or SSA even makes it easy to complete the most drastic of design revisions.

Create Dynamic Label Expressions



Label Expressions

What label expressions **CAN** do:

- Perform mathematical calculations
- Output values based on simple if/then logical statements

What label expressions **CAN NOT** do:

- Utilize text strings in either input or output
- Utilize reference object data
- Utilize information from more than one single object to perform calculations

Label Expressions - Functions

ABS(x)	Returns the absolute value of x.
ACOS(x)	Returns the arccosine of x.
ASIN(x)	Returns the arcsine of x.
ATAN(x)	Returns the arctangent of x.
ATAN2(y,x)	Returns the arctangent of y/x in the correct quadrant based on sines of x and y.
CEIL(x)	Ceiling function: returns the smallest integer that is not less than x. For example, CEIL(1/3) is 1.
COS(theta)	Returns the cosine of theta.
COSH(theta)	Returns the hyperbolic cosine of theta.
COT(theta)	Returns the cotangent of theta.
COTH(theta)	Returns the hyperbolic cotangent of theta.
CSC(theta)	Returns the cosecant of theta.
CSCH(theta)	Returns the hyperbolic cosecant of theta.
DEG2GRD(theta)	Converts theta in degrees to gradians.
DEG2RAD(theta)	Converts theta in degrees to radians.
DRVSTN(x)	Returns the derived station from a raw station x, using the station equations. This function is meaningful only for entities that support station equations (alignments, vertical alignments, sample lines, graph profiles, pipes and structures).
EXP(x)	Returns the exponential of x.
FLOOR(x)	Returns the largest integer that is less-than or equal to x. For example, FLOOR(3/2) is 1.
FMOD(x,y)	Returns the floating point remainder of x/y.
GRD2DEG(theta)	Converts theta in gradians to degrees.
GRD2RAD(theta)	Converts theta in gradients to radians.

IF(test,true_val,false_val)	Evaluates test - if test is non-zero evaluates and returns true_val else evaluates and returns false_val. True_val and false_val can be any expression.
LOG(x)	Returns the log (base e) of x.
LOG10(x)	Returns the log (base 10) of x.
MAX(a,b)	Returns maximum value of a and b.
MIN(a,b)	Returns minimum value of a and b.
POW(x,y)	Returns x raised to the y power.
POW10(x)	Returns x raised to 10.
RAD2DEG(theta)	Converts theta in radians to degrees.
RAD2GRD(theta)	Converts theta in radians to gradians.
ROUND(x)	Rounds x to the nearest integer.
ROUNDDOWN(x)	Rounds x down to the nearest integer. For example, ROUNDDOWN(1.9) is 1.
ROUNDUP(x)	Rounds x up to the nearest integer. For example, ROUNDUP(2.1) is 3.
SIN(theta)	Returns the sin of theta.
SEC(theta)	Returns the secant of theta.
SECH(theta)	Returns the hyperbolic secant of theta.
SINH(theta)	Returns the hyperbolic sin of theta.
SQR(x)	Returns x squared (x*x).
SQRT(x)	Returns the square root of x.
TAN(theta)	Returns the tangent of theta.
TANH(theta)	Returns the hyperbolic tangent of theta.
TRUNC(x)	Truncates x to an integer value.



Label Expressions - Operators

Symbol	Operator Definition
=	logical equals
!=	logical not equals
!	logical not
<	logical less-than
>	logical greater-than
<=	logical less-than or equals
>=	logical greater-than or equals
And	Boolean "AND"
~	logical approximately equal
<~	logical less-than or approximately equal
>~	logical greater-than or approximately equal
Or	Boolean "OR"
+	binary addition
-	binary subtraction
*	binary multiplication
/	binary division
-	unary minus
+	unary plus
^	power

Label Expressions – Results Formats

Expression Results may be formatted as follows:

Angle	Elevation
Area	Grade / Slope
Azimuth	Latitude
Coordinate	Longitude
Dimension	Percent
Direction	Rotation
Distance	Station
Double	Volume

The numerical results will adhere to the units assigned in the drawing settings of a .dwg file, and they may be displayed with alternative units through label and table styles.

Let's jump into Civil 3D

Reference the class handout during live demos

Extra Credit!

What is the estimated depth percentage in a circular pipe at which the pipe is flowing at its maximum capacity?

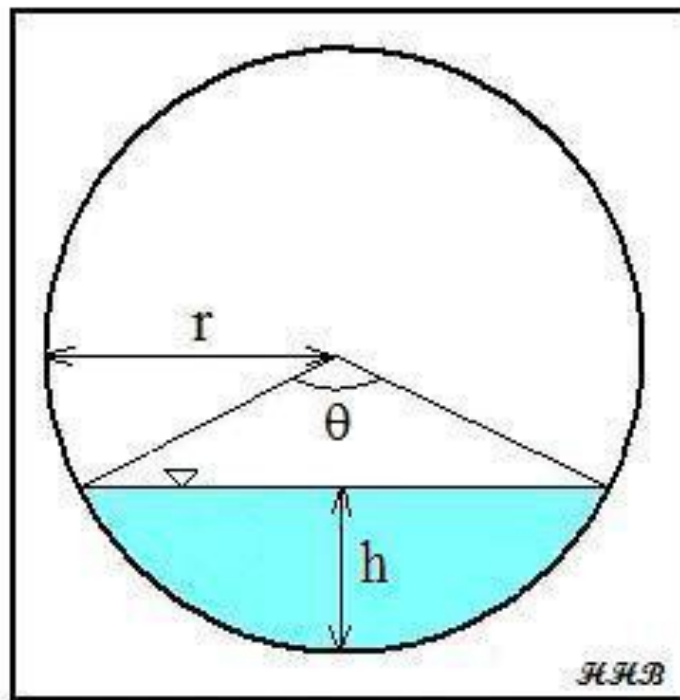


Figure 1. Partially Full Pipe Flow Parameters (Less than Half Full)

$$r = \frac{D}{2} \quad h = y$$

$$\theta = 2 \arccos \left(\frac{r-h}{r} \right)$$

$$A = \frac{r^2(\theta - \sin \theta)}{2}$$

$$P = r\theta$$

$$R_h = A/P$$

y = flow depth

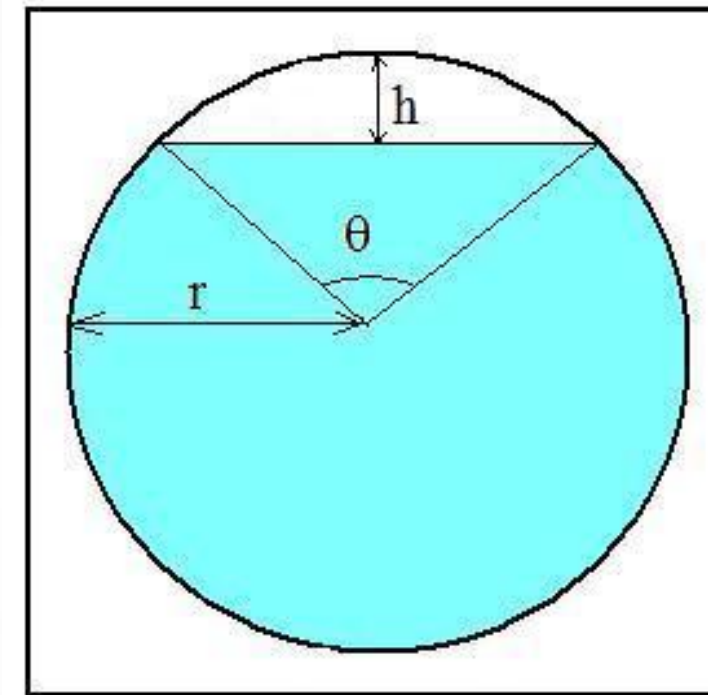


Figure 2. Partially Full Pipe Flow Parameters (more than half full)

$$r = D/2 \quad h = 2r - y$$

$$\theta = 2 \arccos \left(\frac{r-h}{r} \right)$$

$$A = \pi r^2 - \frac{r^2(\theta - \sin \theta)}{2}$$

$$P = 2\pi r - r\theta$$

$$R_h = A/P$$

y = flow depth

Calculate Q_{max}!

*Images Courtesy of:
Spreadsheet Use for Partially Full Pipe Flow Calculations; Harlan H. Bengtson, PhD, P.E.

Label Expressions

What are some other possible examples of Civil 3D model calculations that may be helpful during design or for full plan production labels?

- Friction loss in a pipe

$$H_f = [29 n^2 L V^2] / [(R^{4/3}) (2g)]$$

Where:

H_f = total head loss due to friction (ft)

D = diameter of pipe (ft)

L = length of pipe (ft)

V = mean velocity (ft/s)

R = hydraulic radius (ft)

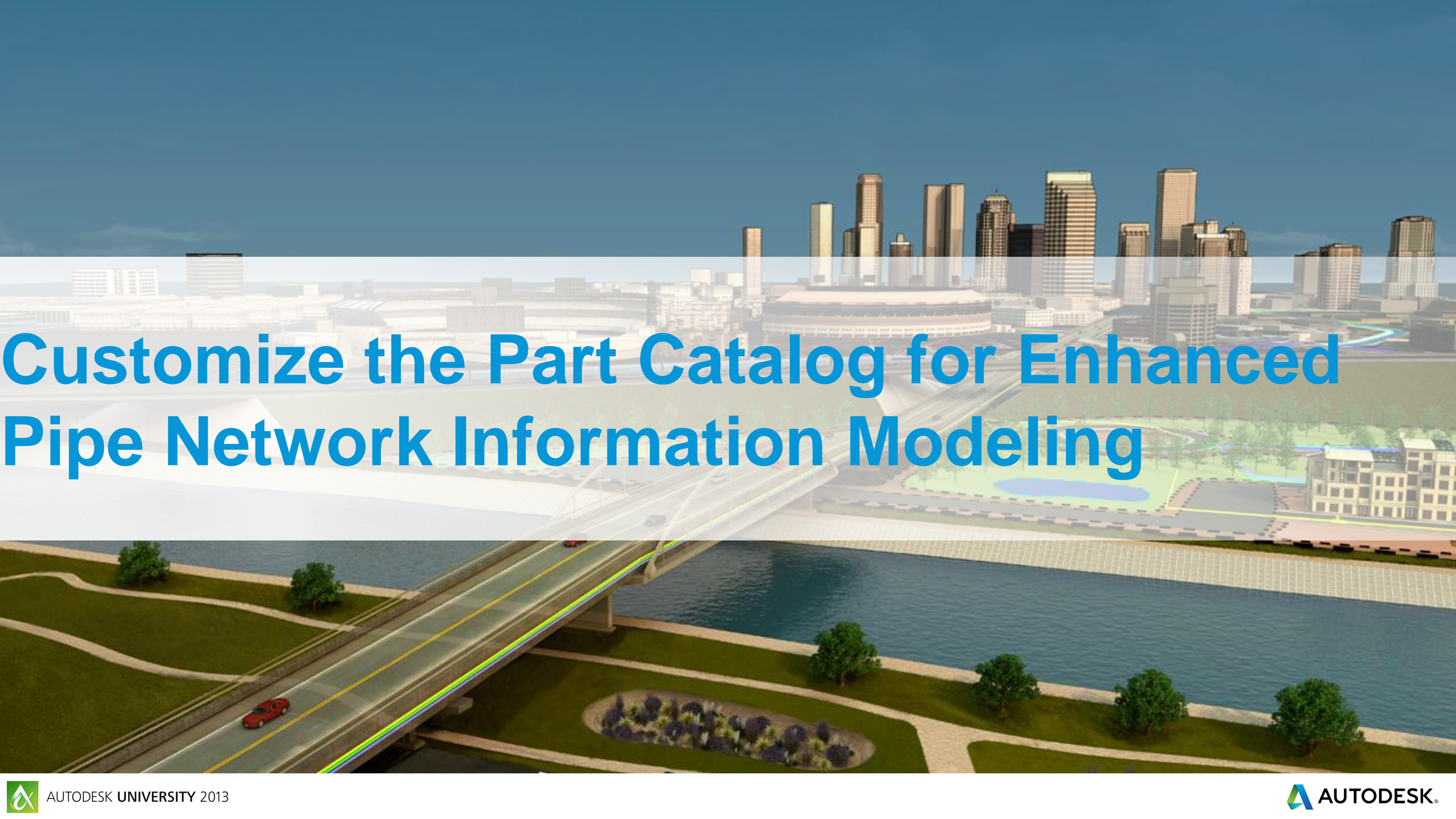
g = acceleration of gravity - 32.2 ft/s²

- Anticipated deflection based on max cover?

- May need a custom parameter for backfill type

- Stone initial backfill material quantity based on a typical initial backfill cross section (e.g. 4" bedding, pipe dia. + 24" trench width, crushed stone to 6" over top of pipe)

- The possibilities are endless! What are your recommendations?

An aerial view of a city with a bridge over a river. A colorful, multi-colored line representing a pipe network is overlaid on the bridge and extends into the city. The text "Customize the Part Catalog for Enhanced Pipe Network Information Modeling" is written in large blue letters across the center of the image.

Customize the Part Catalog for Enhanced Pipe Network Information Modeling

Part Catalog Customization

The default Part Catalog may be found at:

C:\ProgramData\Autodesk\C3D 2013\enu\Pipes Catalog

FOR A MULTI-USER ENVIRONMENT, YOU MUST HAVE A SHARED PART CATALOG!

Failure to create and maintain a shared catalog that all users working together are pathed to will result in problems

Part Catalog Customization

The main XML file that will need to be modified for catalog customization is:

C:\ProgramData\Autodesk\C3D 2014\enu\Pipes Catalog\Aecc Shared Content\AeccPartParamCfg.xml

Other XML files that will need to be modified for list sorting and management for optional parameters are:

C:\ProgramData\Autodesk\C3D 2014\enu\Pipes Catalog\US Imperial Pipes\AeccSharedPropertyLists.xml

C:\ProgramData\Autodesk\C3D 2014\enu\Pipes Catalog\US Imperial Structures\AeccSharedPropertyLists.xml

For the SI system community, replace the “US Imperial” with “Metric”

Part Catalog Customization

One more important note...

Setting the Part Catalog in Civil 3D will not pick up any differences in the XML files that have been edited. If you change the Catalog Folder, you must restart Civil 3D for the new XML files to be read.

Let's jump into the XML files and Civil 3D

Reference the class handout during live demos

Part Catalog Customization – XML to Civil 3D Comparison

XML Configuration:

```
<AeccOptParam context="Material_Type"/>
<AeccOptParam context="MinCurveRadius"/>
<AeccOptParam context="FlowAnalysis_Manning"/>
<AeccOptParam context="FlowAnalysis_HazenWilliams"/>
<AeccOptParam context="FlowAnalysis_DarcyWeisbach"/>
<!-- Custom Optional Parameters by GSP Employees-->
<AeccOptParam context="FlowAnalysis_DesignStorm"/>
<AeccOptParam context="FlowAnalysis_Velocity"/>
<AeccOptParam context="EquivalentRound"/>
</AeccPartTypeCfg>
</AeccPartDomainCfg>
- <AeccPartDomainCfg domain="Structure_Domain">
  <AeccReqParam context="StructBoundingShape"/>
  <AeccReqParam context="StructVertPipeClearance"/>
  <AeccShpParam context="StructHeight"/>
  <AeccShpParam context="StructDiameter"/>
  <AeccShpParam context="StructWidth"/>
  <AeccShpParam context="StructLength"/>
  <AeccOptParam context="Material_Type"/>
  <AeccOptParam context="PartSizeValidation_Test"/>
  - <AeccPartTypeCfg desc="Junction Structure" type="Struct_Junction">
    <AeccReqParam context="StructRimToSumpHeight"/>
    <AeccReqParam context="WallThickness"/>
    <AeccReqParam context="FloorThickness"/>
    <AeccOptParam context="StructFrame"/>
    <AeccOptParam context="StructGrate"/>
    <AeccOptParam context="StructCover"/>
    <AeccOptParam context="StructFrameHeight"/>
    <AeccOptParam context="StructFrameDiameter"/>
    <AeccOptParam context="StructFrameLength"/>
    <AeccOptParam context="StructFrameWidth"/>
    <AeccOptParam context="StructFrameHeight"/>
    <AeccOptParam context="StructBarrelHeight"/>
    <AeccOptParam context="StructBarrelPipeClearance"/>
    <AeccOptParam context="StructConeHeight"/>
    <AeccOptParam context="StructSlabThickness"/>
    <AeccOptParam context="StructRiserHeight"/>
    <AeccOptParam context="StructInnerDiameter"/>
    <AeccOptParam context="StructInnerLength"/>
    <AeccOptParam context="StructInnerWidth"/>
    <!-- Custom Optional Parameters by GSP Employees-->
    <AeccOptParam context="StructGrateSize"/>
    <AeccOptParam context="FlowAnalysis_DrainageArea"/>
    <AeccOptParam context="FlowAnalysis_RunoffCoefficient"/>
    <AeccOptParam context="FlowAnalysis_TimeOfConcentration"/>
    <AeccOptParam context="FlowAnalysis_QCaptured"/>
    <AeccOptParam context="FlowAnalysis_Intensity"/>
  </AeccPartTypeCfg>
  - <AeccPartTypeCfg desc="Inlet-Outlet Structure" type="Struct_InletOutlet">
    <AeccReqParam context="StructHwBaseWidth"/>
```

Structure Properties - Structure - (1)

Structure Properties	Value
Inlet Location	On Grade
Part Data	
Part Type	Junction Structure
Part Subtype	Rectangular
Part Description	Rectangular Structure Slab Top Rectangular Frame
Part Size Name	36 x 36 Rect Structure 30 x 30 Frm
Structure Shape	Box
Vertical Pipe Clearance	6.00"
Rim to Sump Height	4.146'
Wall Thickness	6.00"
Floor Thickness	6.00"
Material	Reinforced Concrete
Frame	Standard
Grate	Standard
Cover	Standard
Frame Height	6.00"
Frame Diameter	
Frame Length	30.00"
Frame Width	30.00"
Barrel Height	
Barrel Pipe Clearance	2.00"
Cone Height	
Slab Thickness	4.00"
Inner Structure Length	36.00"
Inner Structure Width	36.00"
Grate Size	0.00"
Drainage Area	
Runoff Coefficient	
Time of Concentration	0
Flow Captured	
Design Intensity	
Structure Height	4.646'
Structure Width	48.00"

An aerial view of a city with a bridge over a river. A rainbow-colored line, representing a hydrology model, runs along the bridge and into the river. The city skyline is visible in the background.

Customize Parcel Styles and User Defined Properties for Hydrology Information Modeling

H&H Parcel Workflows

Why use Parcels instead of Catchments?

- Parcels allow for more robust visualization / styles.
- Parcel area labels may be manipulated much easier.
 - Catchment object labels seem to default to the centroid, and the anchor point cannot be moved. This is problematic for dragged-state styles.
- Parcels allow for User Defined Properties and Classifications. Unlimited amount of model information may be added to your H&H workflows, which will also result in greater possibilities for labels, expressions, and tables.

H&H Parcel Workflows

Here are the steps for setting up your own templates for H&H workflows with Parcels:

- Create C3D sites for each type of Hydrology method to be used. Also, create separate sites for the “Overall” watersheds/catchments and the “Surface Type” watersheds/catchments.
- Set up User Defined Properties for H&H parcels. This is where the engineering begins. Include company engineers and hydrologists into the decision-making.
- Create area label expressions for H&H parcel labels.
- Set up area label styles and table styles for your final drainage map output.

Let's jump into Civil 3D

Reference the class handout during live demos.

Note: This class was not designed to show all of the parcel H&H workflows. We will cover as much as we can, based on time availability.

An aerial perspective of a cityscape. In the foreground, a multi-lane bridge with a rainbow-colored light strip along its side spans a wide river. A red sports car is driving on the bridge. To the right of the river, there's a green park area with trees and a blue oval-shaped pond. In the background, a large stadium with a white roof is visible, surrounded by various city buildings and skyscrapers under a clear blue sky.

Create or Customize Standard Templates for Advanced H&H Workflows



H&H Templates

What's in a good H&H Template?

- Civil 3D Feature Settings
- Good starting Parts Lists and Rule Sets
- Pipe and Structure Styles
 - Plan, Profile, and Crossing Pipes
- Pipe and Structure Label Styles
 - Label Expressions to perform calculations
- Pipe and Structure Table Styles
- H&H Parcel Styles
- Parcel Area Label Styles
 - Hydrologic watersheds
 - Hydraulic calculation catchments
- Parcel Area Table Styles
- Catchment Styles

- Final Quote:

In the world of business technology the opposite of evolution is not regression, but extinction.

Thanks For Coming Don't Forget To Take The Class Survey!

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C3D-Nash

