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Under the Radar: Complex Tunnel Design in InfraWorks

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Learning Objectives

- Learn how to build complex underground tunnels using InfraWorks and Inventor.
- Learn how InfraWorks Tunnel Models integrate with Inventor, Civil 3D, and Revit.
- Discover lessons learned by HNTB.
- Learn what's new and what's next (Live Demo)

Description

`AIA CEU`   This session will highlight the latest tunnel-design capabilities in InfraWorks software, and how HNTB is adopting these new tools and workflows to design and document complex underground tunnels for clients. See how Autodesk has been working with HNTB to advance InfraWorks software's latest features in the tunnel-design process, and learn more about its integrations with Inventor software, Civil 3D software, and Revit software.

About the Speakers

Kyle Gerke is a BIM Manager for HNTB and has almost 10 years of experience in the AEC industry. He also supports 3D Visualizations for pursuits and has been a BIM Coordinator on large scale Design Projects, including Water Treatment Facilities, Airports and Bridges. His skills include software integration, multidisciplinary modeling, clash resolution and creating visualizations. His passion is to identify and utilize the best tools available, focusing on automation and seamless integration, to get the most out of a project model during all stages of design & construction.

Scott Lecher is a VDC Systems Lead at HNTB with 20 years of experience. Scott's background is in roadway design and parametric surface modeling to support delivery of plans, specs, and estimates for construction documentation. Scott is also a software developer proficient in automation and systems integration. He is an ardent supporter of Open BIM for infrastructure and enjoys bringing a data-focused mindset to collaboration across the entire asset life-cycle from planning to design and construction, then through handover to operations and maintenance.

Ara Ashikian is a Senior Product Line Manager for the Autodesk Civil Structures product development teams. Prior to joining Autodesk in 2013, Ara gained over 20 years of experience as a bridge engineer and a software developer. His experience includes bridge design experience in preliminary, detailed and construction engineering design aspects for a wide range of bridge types. His projects included the detailed construction engineering of the EG LNG suspension bridge in Africa, as well as for the New Bay Bridge (self-anchored suspension bridge in California), the detailed engineering for the launching of the Kicking Horse Canyon in the Canadian Rockies as well as for the cable-stayed Coast Meridian bridge.

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Learning Objective 2 – How To Build a Complex Underground Tunnel

Purpose

InfraWorks is best at quickly designing 3D horizontal infrastructure in-context, such as tunnels, roadways, bridges, drainage systems, and surfaces. Given this ability and with its design tool functionality rapidly advancing, particularly with tunnels, InfraWorks can start to be utilized as the authoring 3D model platform. Also, the integration capabilities allow InfraWorks to connect to software that is best at performing other tasks, like creating parametric parts or documenting a set of drawings. Integration between vertical and horizontal models has not proven to be very effective in the past but is starting to become a reality. Understanding the processes and limitations described in this handout may help you determine what workflow is best for your project(s).

Process

The diagram below shows the primary software connections that enable the workflow of "**Federated Design in InfraWorks and Document in Revit and Civil 3D.**"
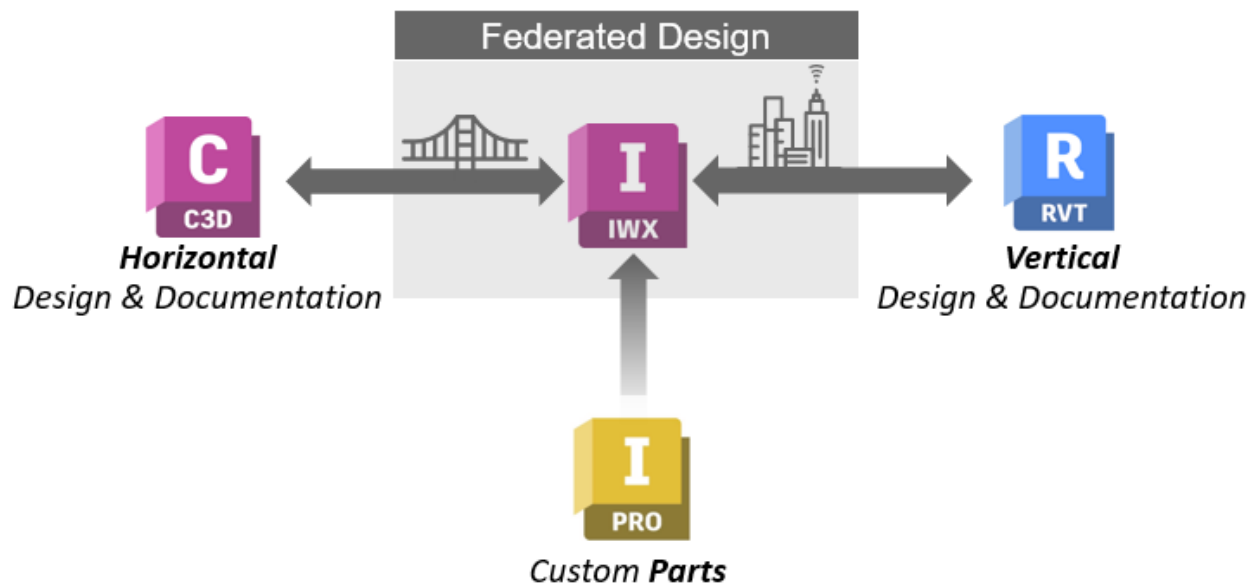
Federated Design – can start with Model Builder to generate an existing geolocated project that builds the terrain, roads, buildings, landscaping etc.
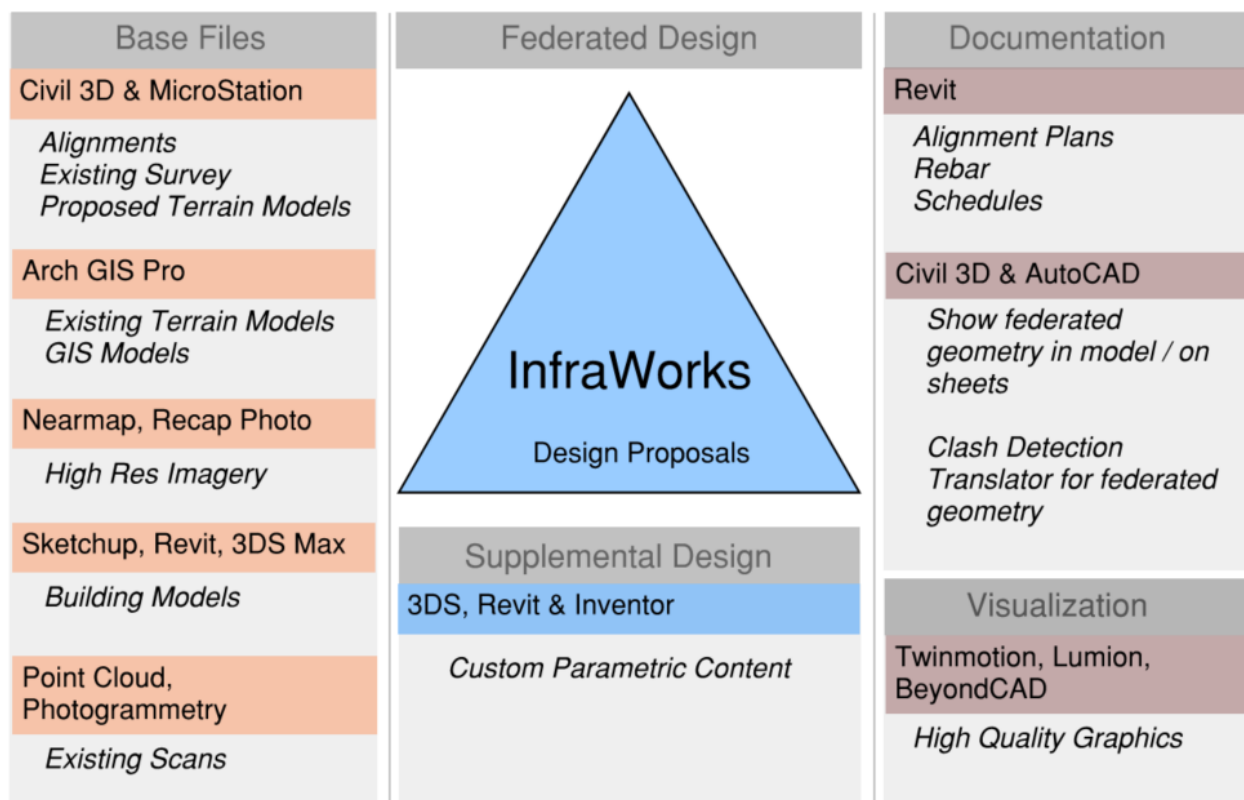
Horizontal – create an alignment from scratch in InfraWorks, or import external alignment data that may already be developed to take over the horizontal design in InfraWorks

Custom Parts – utilize parametric parts for quick tunnel editing (cross sections and generic objects to place along tunnel alignment)

Vertical – publish civil structure and import the IMX into Revit & Civil 3D to create construction documentation

Workflow Breakdown

The chart below shows some additional design applications and the integrated purpose they may serve in the federated design model. For example, Inventor for creating parametric content, Revit for documenting sheets and modeling rebar, etc.

Base Files	Federated Design	Documentation
Civil 3D & MicroStation *Alignments* *Existing Survey* *Proposed Terrain Models*		**Revit** *Alignment Plans* *Rebar* *Schedules*
Arch GIS Pro *Existing Terrain Models* *GIS Models*	**InfraWorks** Design Proposals	**Civil 3D & AutoCAD** *Show federated geometry in model / on sheets* *Clash Detection Translator for federated geometry*
Nearmap, Recap Photo *High Res Imagery*		
Sketchup, Revit, 3DS Max *Building Models*	**Supplemental Design**	**Visualization**
Point Cloud, Photogrammetry *Existing Scans*	**3DS, Revit & Inventor** *Custom Parametric Content*	**Twinmotion, Lumion, BeyondCAD** *High Quality Graphics*

Payoff

A federated InfraWorks model provides many added benefits. Here is a list of some of the benefits of modeling in InfraWorks:

- **Advanced in-context modeling:** before you even start proposed modeling, InfraWorks can build your existing project site with model builder. 3D buildings, bridges, roads, and terrain are generated and can be modified if needed. Multiple proposals can be modeled in a workshare environment, and geometry can be added from the large library of Civil components or imported from external software and editable within InfraWorks.

- **Better coordinated models:** real-time 3D review can occur during all stages of design for better decision making. InfraWorks models are viewable in the ACC model viewer and can be brought into Navisworks for clash detection.

- **Visualization Benefits:** impress stakeholders with presentation graphics and walkthroughs that can be created inside InfraWorks! Many 3D Visualization platforms are oriented around Architecture but with storyboarding, infrastructure animations can live right inside your in-context modeling platform.

- **Integration and Data Exchange Capabilities**: export to advanced Visualization applications like Twinmotion, Lumion, and BeyondCAD. You can export data to excel to quickly update attributes. You can utilize the Civil Structures connections to bridge the Civil 3D and Revit data exchange gap. InfraWorks is ideal for integrating vertical and horizontal information. See image below for some of the file types that can be brought into the platform:

In addition to integration options shown in the workflow breakdown chart, this image shows data sources that can also be brought into InfraWorks.

Keep in mind, you can bring external files into InfraWorks at any stage of your design to take advantage of some of these added benefits, even if InfraWorks isn't being used as the authoring model.

Infraworks Setup

Typically, proposal models will utilize **Model Builder** to build an existing conditions start to your project model (created from OpenStreetMap and other data sources).

Option 1: From the Infraworks home page, select the "Model Builder…" option. You will then be prompted to search a location, and select the extents of the 3D modeled environment. Depending on the coverage location, the accuracy of terrain, roads, and buildings may be at a rudimentary level. Importing Survey data will give you the most accurate terrain, but is not always available during the early stages of design. You can check out these free Global Data Source sites for additional DEM terrain data (Digital Elevation Models) [Link](#)

Option 2: If you create a model by selecting the "New…" option from the Infraworks home page, then you will start with a blank model environment, without any existing terrain, buildings, or roads on your site. (QGIS, ArcGIS)

Setting up Coordinates
Make sure to select the appropriate coordinate system when setting up your model, since this cannot be changed after your model has been created. This will establish the geolocation so you can import data that has the same coordinate system.
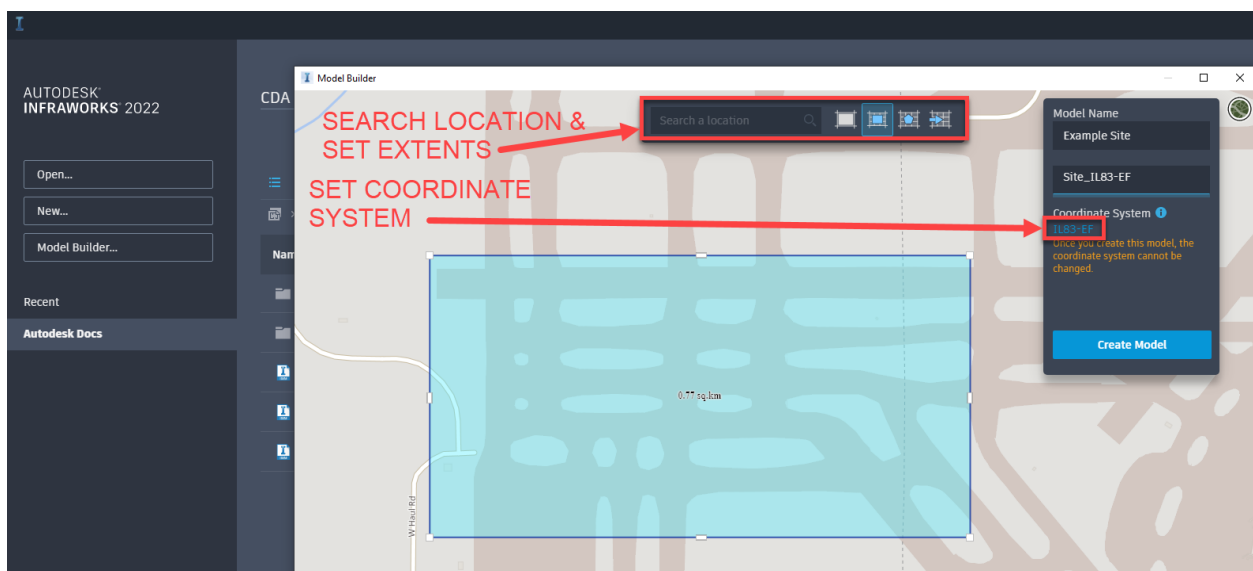
Import Alignment & Inventor Part

As with most linear projects, the tunnel workflow typically starts with horizontal and vertical alignment. Although the alignment can be created and modified within InfraWorks (as a component road), typically, the data originates in Civil 3D or MicroStation. For this workflow, we recommend the design team imports any external alignments that have been developed and take over that design in-context of InfraWorks.

I created a couple Screencasts to run through the process of building a tunnel. The first video can be viewed here:

Knowledge Network Video: InfraWorks + Inventor Process

This video captures "How To":
- Importing C3D data source (alignment with vertical and horizontal data)
- Configure and filter out excess alignment and corridor (comes in as a road)
- Add tunnel structures to road
- Import parametric part into style palette
- Assign domain and component type to tunnel segment
- Confirm parameters were translated
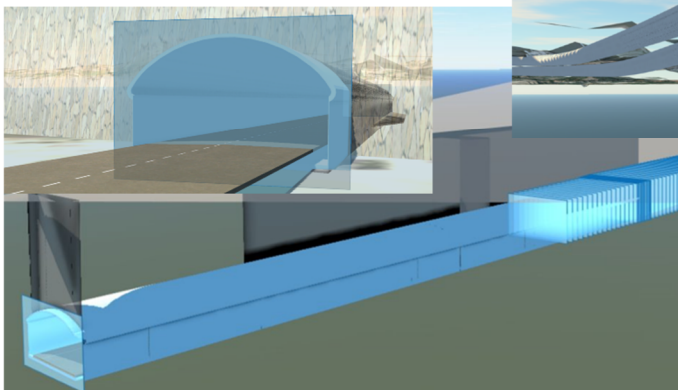- Modify horizontal and vertical alignment (hold Alt to keep constrained)

Not shown in this video is switching between different types of tunnels. Here are some screen captures that show the defaults:

submerged tunnel
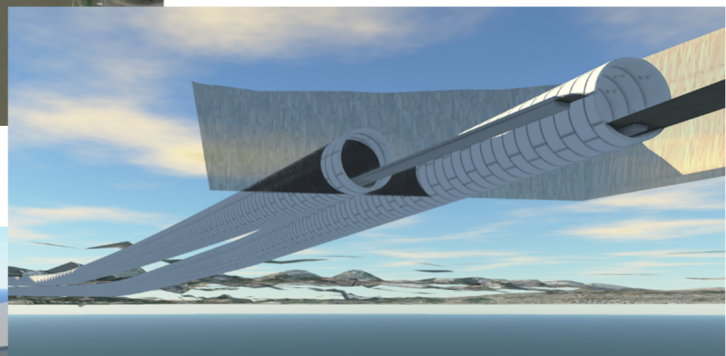
bored tunnel



cut and cover

Build Tunnel Geometry

This second video shows how to modify the tunnel further to achieve various complexities.

Knowledge Network Video: [InfraWorks Slices and Generic Models](#)

This video captures "How To":
- Create, copy, duplicate tunnel cross sections / slices
- Adjust parameters of tunnel segment directly in InfraWorks user interface (allows for variation in tunnel geometry at specific linear alignment stations)
- Add generic objects along alignment
- Skew, group, and offset objects
- Export tunnel data to excel to manage parameters externally (add slices and manipulate data)

No Shown in this video is how to setup the connection. Once you're ready to bring the tunnel into Revit and/or Civil 3D, select the tunnel, right-click and select Publish Civil Structures. Then specify a location to place your IMX file that can be brought into Revit and Civil 3D:
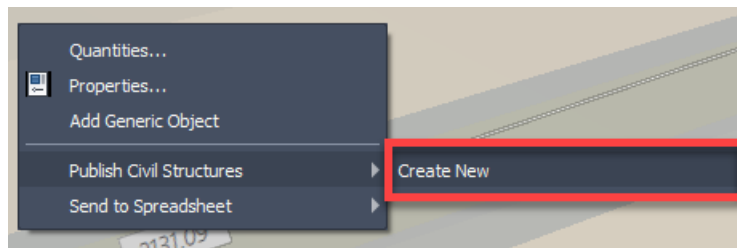
Refer to the Revit Integration Setup Section in the next Objective for next steps to documentation in Revit.

Learning Objective 3 – Infraworks Integration: Inventor, Revit, and Civil 3D

Integration Workflow Overview

In the previous section we went through the purpose, process, payoff, and setup in InfraWorks. In this section we will go into some detail on how to setup the dynamically integrated connection with Inventor, Revit, and Civil 3D. This will enable parametric model control within InfraWorks and documentation outside of InfraWorks.

Inventor | Parametric Part

InfraWorks can read Inventor parts and assemblies along with any parameters specified for in-context control. First, create a 2D sketch, and add extrusions based on the level of detail required. Then set "key" parameters and iLogic rules using features and formulas create a parametric part. Let's review the process.

Create your sketch – make sure all dimensions are fully constrained:
(Note: this can be done before or after you setup the user parameters, shown in the next step)
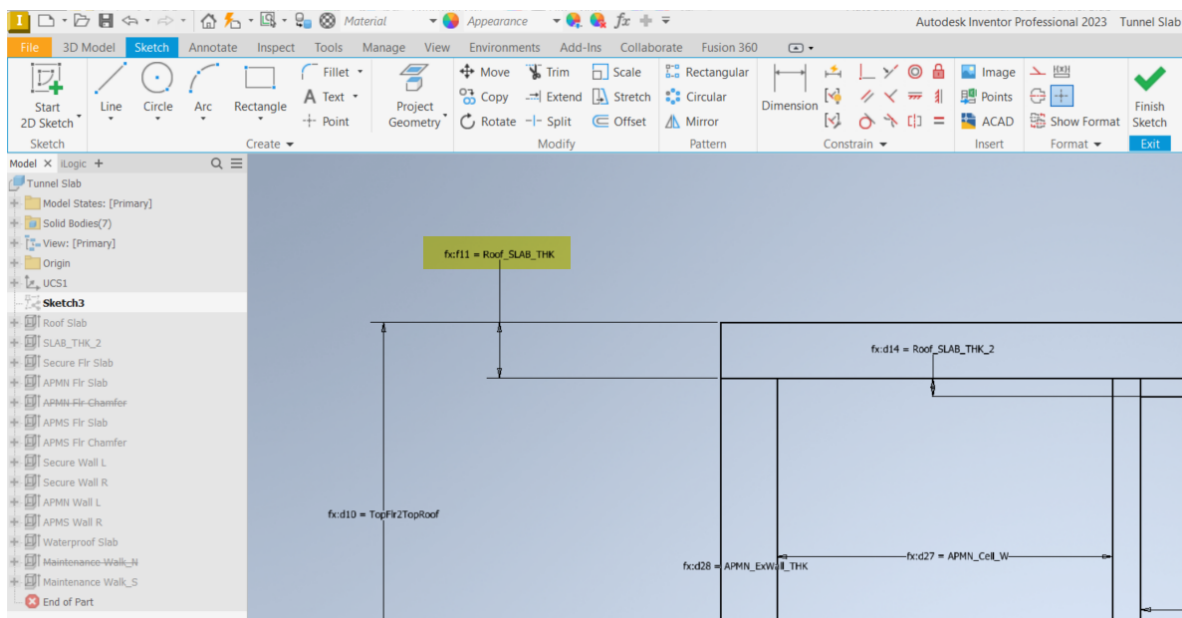
Create your parameters: (make sure to check the "Key" parameter box to be able to control the dimension within InfraWorks)
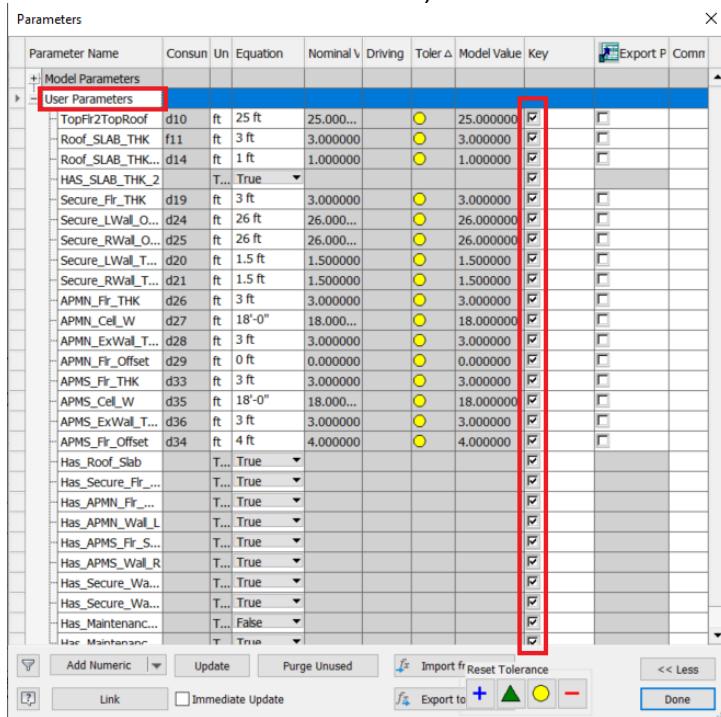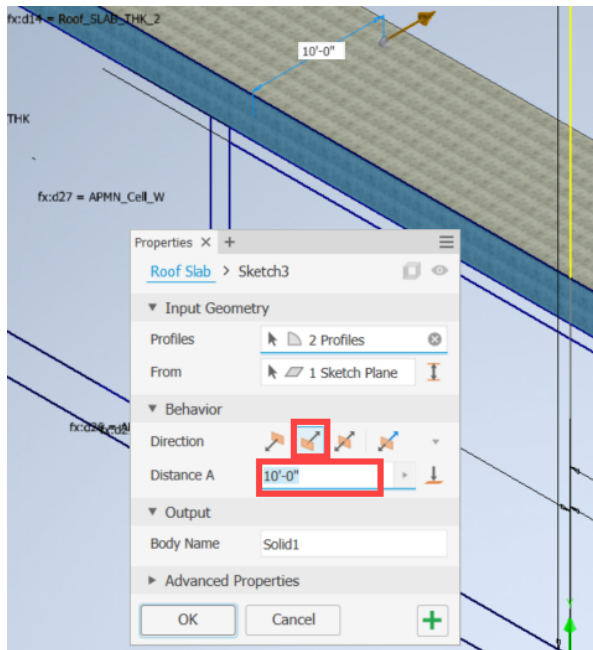

Tip: If you create all parameters up front, you can assign to dimensions as you go, or once all dimensions have been added. Just right-click each dimension to assign to a parameter.

Create an Extrusion from your sketch. 3D Model Tab > Extrude, then select a closed face:
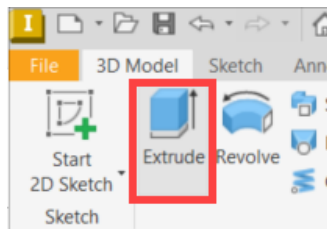
Add an arbitrary thickness so your .ipt file can be recognized when imported into InfraWorks:


Important: make sure your parts / assemblies have a consistent UCS orientation as well as consistent extrusion direction in relation to the XYZ plane. This will ensure they are accurately brought into InfraWorks.

Advanced Parameters (iLogic). A common need when modeling is the ability to control what and when things appear. For example, you may need to control the visibility of an object, or only show one object visible, if another object is also visible. This can be a bit tricky to setup since it requires manipulating code. Let's review the setup for an Inventor part, which is similar for assemblies.
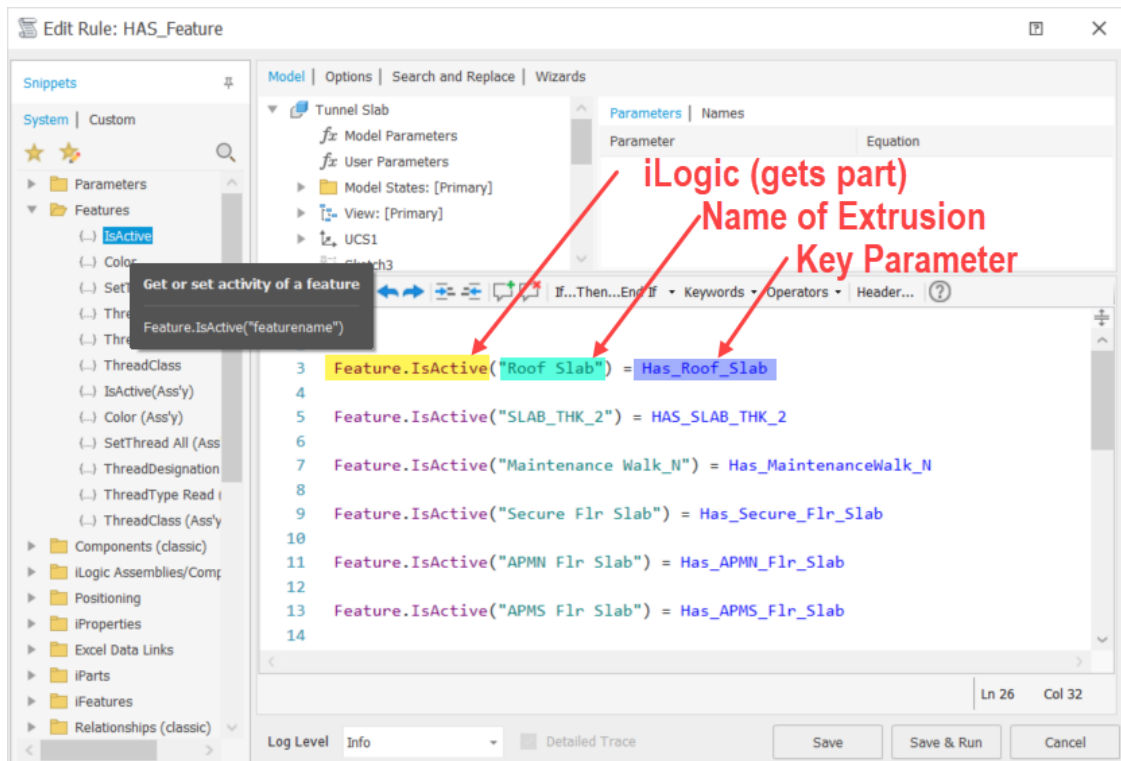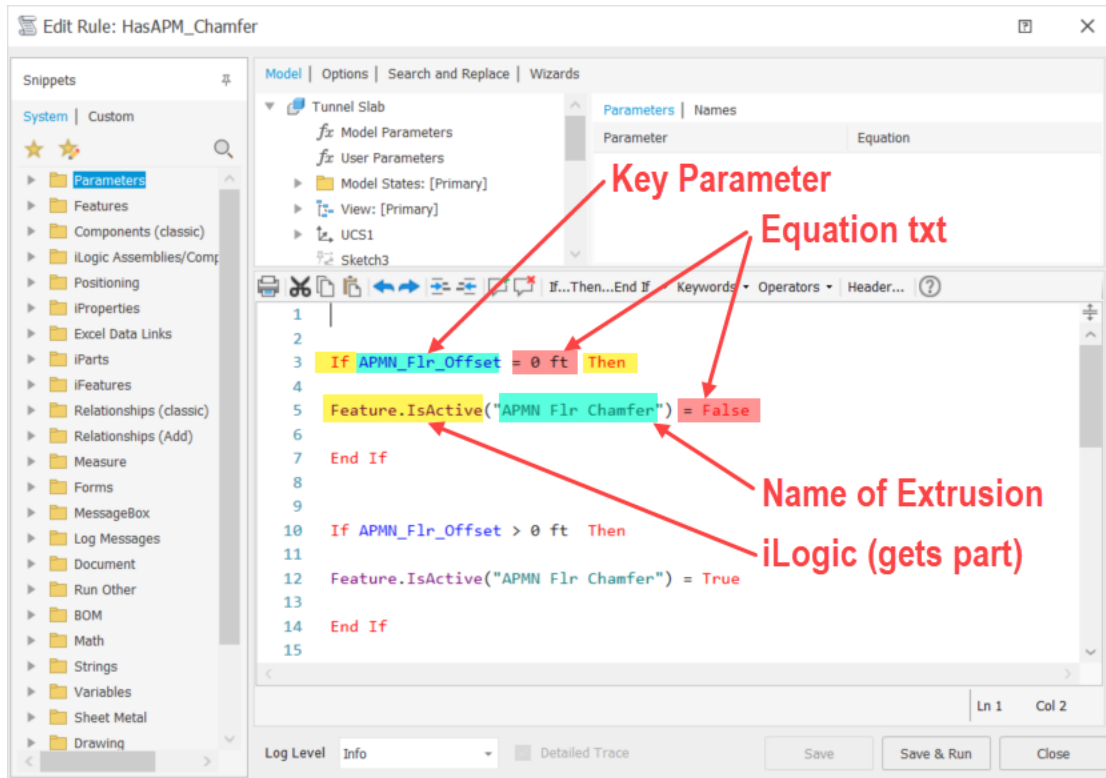
First, add a True/False Parameter: (Check "Key" box)
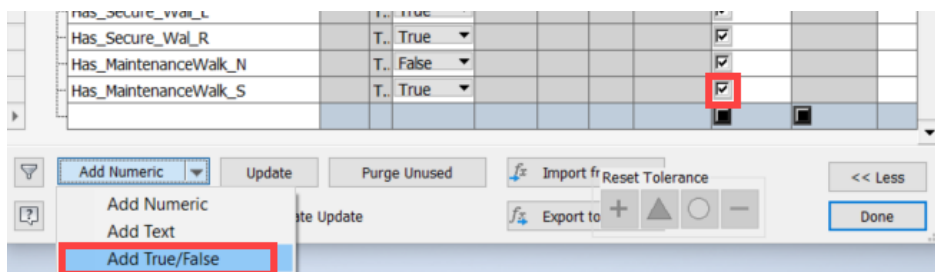
Next, add logic built from parameters and sketched parts.
Select the iLogic Tab > Add Rule:
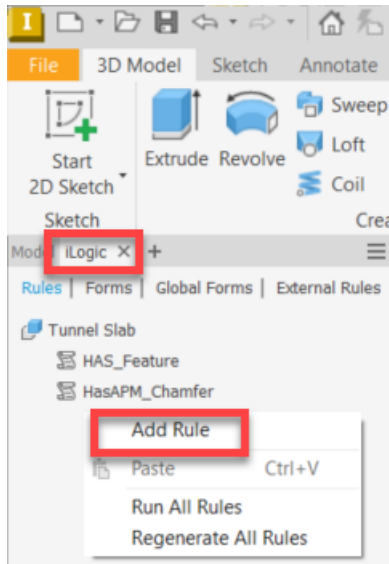
Add a True/False rule, refer to any row of code below: (see red text for code breakdown)

Here is an example that breaks down the code use in "If / Then" formulas:

Note, there is no need to assign iLogic rules in the parameters window, the association happens in the code.

You can now save you. ipt or .iam file for use in InfraWorks!

If you would like to learn more modeling techniques in Inventor, see the links below. These videos have some good tips and go into detail that was not covered in this section.

External Resources:
60 Inventor Tips in 60 Minutes | AU 2017
Inventor iLogic: Beyond the Basics | AU 2017
Autodesk Knowledge Network – Inventor Videos

Revit Integration Setup

Once you have created the Civil Structure IMX export, you are ready to bring the file into Revit & Civil 3D and start creating your construction documents. Place the IMX in a central location so it can be overwritten when updated, to allow for dynamic connection in Revit. It will then be utilized to show in plan views, elevations, sections, and schedules. Revit can also be used for modeling and documenting rebar. Let's review the process in Revit.

To enable Infrastructure tool, go to the File Tab > Options > User Interface:
Then make sure the box is checked.
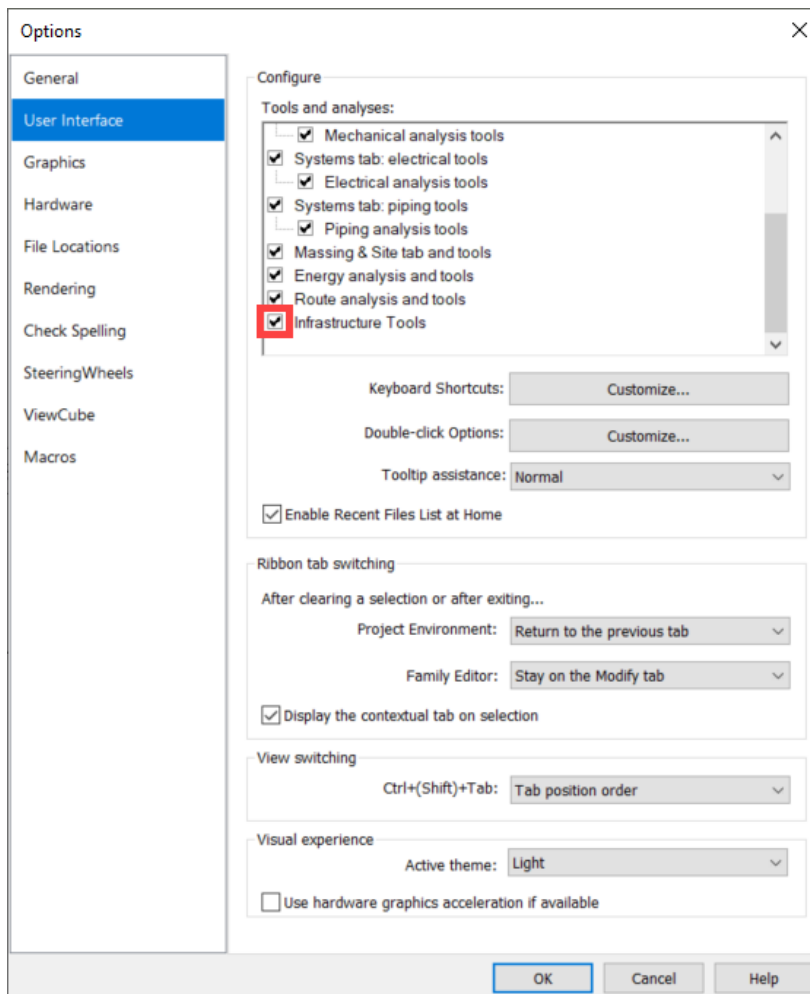
There is now an Infrastructure category option:
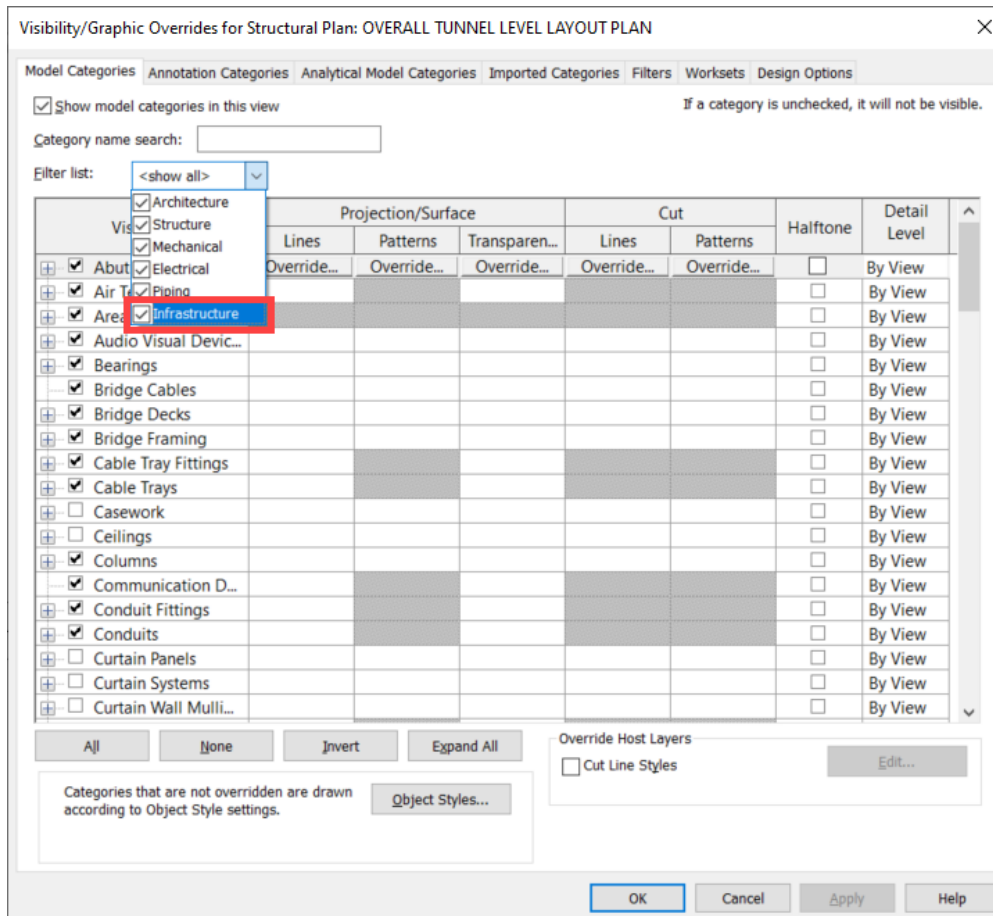
This option enables infrastructure categories such as abutments, piers, expansion joints, and bridge decks. Subcategories and annotation categories including alignments, station labels, and tags for infrastructure model elements are also available.

Now that we have setup the infrastructure tools, let's bring in the InfraWorks model.
Navigate to the Add-Ins Tab > Import Civil Structures:
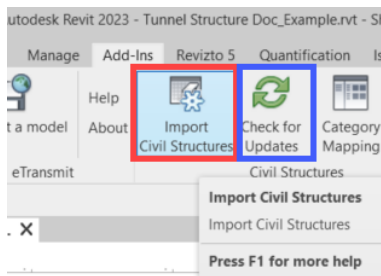
Note, when the IMX file is updated by the tunnel designer, you can select "check for updates" shown above.

The IMX import will translate to generic models and will be selectable based on how the IPT / IAM file was built. Below is an example of the properties that are brought over when selecting the roof slab.
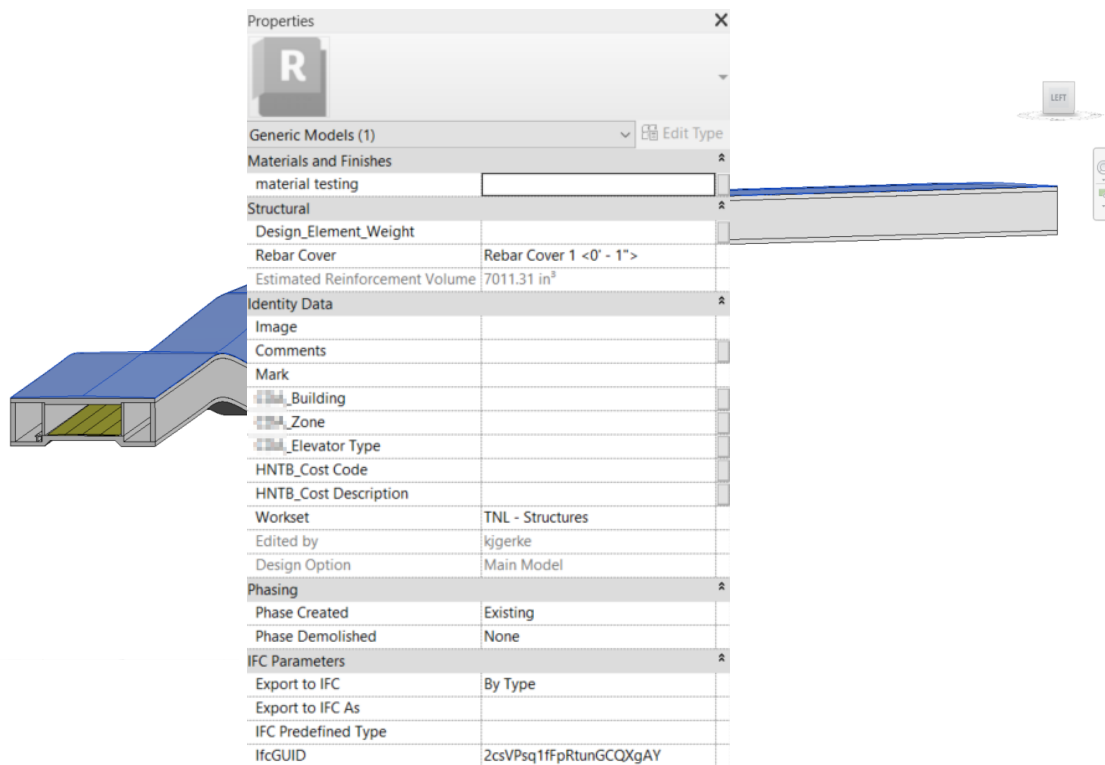

Annotation tools – below shows how Civil Structures supports tags, dimension, and creating station labels. You will find the labels within the Annotate Tab > Alignment Station:
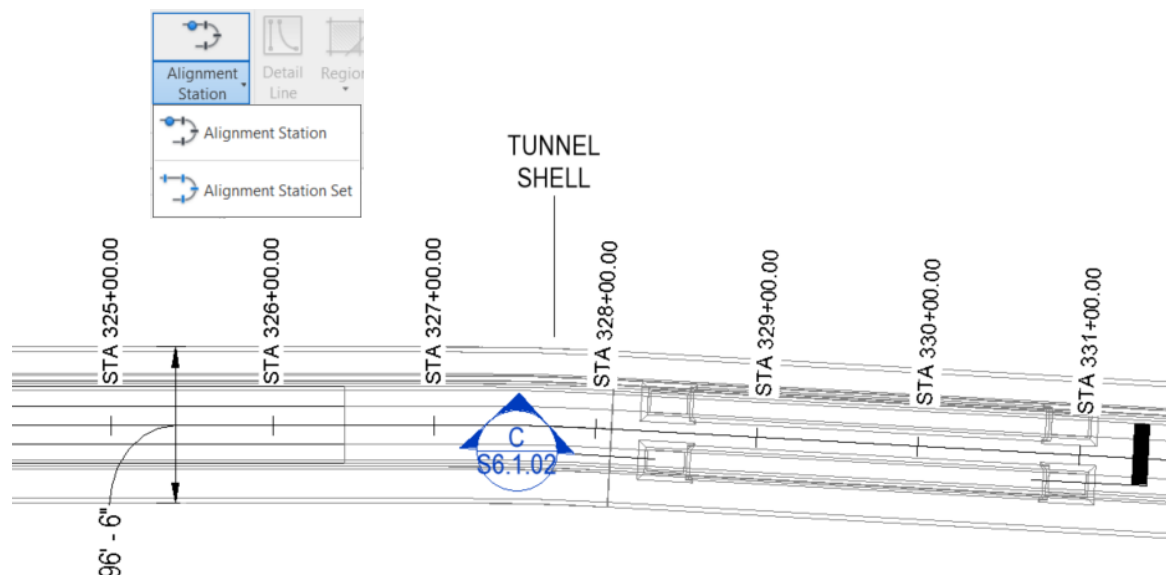
Below is an example how the tunnel is displayed in both cross and longitudinal sections. These dimensions will update accordingly if / when design changes occur.
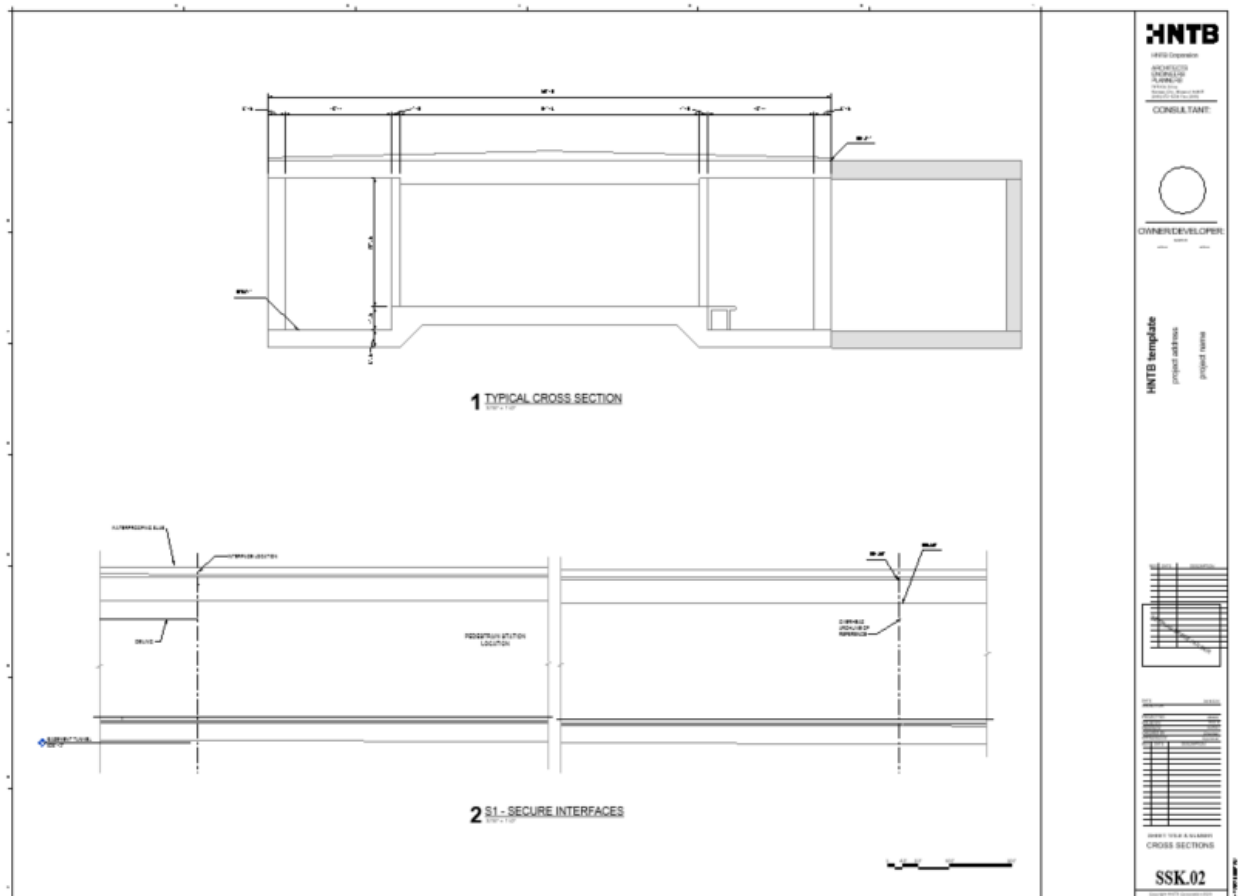
Revit schedules also support Infrastructure categories:
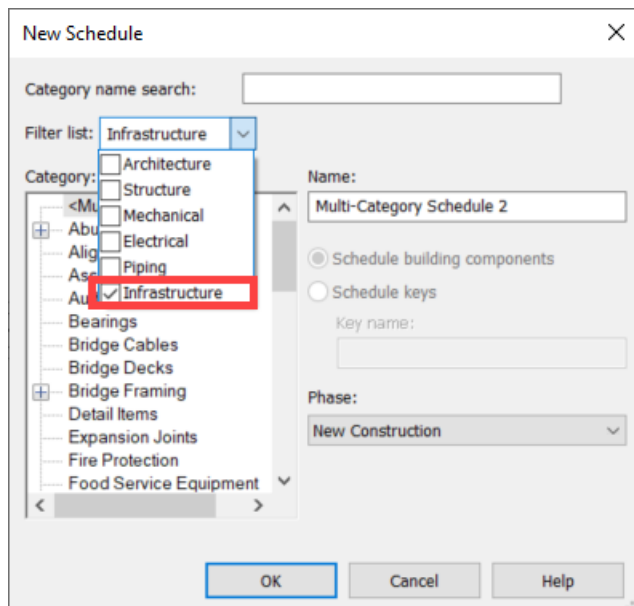
Currently, since tunnels are recognized as generic models, the infrastructure schedule can not be utilized. Here is an example of a quantity take off for generic models:

| Multi-Category Material Takeoff					
Category	Material: Area	Material: Name	Material: Unit weight	Material: Volume	Comments
Floors	182551.50 SF	Default Floor	0.00 lb/ft³	2129799.08 CF	FUTURE
Generic Models	3107950.27 SF	Bridge Concrete	0.00 lb/ft³	4397799.81 CF	TUNNEL SHELL

Free Form Rebar

This video shows the process for adding associative 3D rebar to Civil Structure components.

Autodesk Knowledge Network: [Free Form Rebar](#)

Civil 3D Integration

Currently, the integration functionality in Civil 3D is very limited. You are unable to see Civil Structures in a cross section or profile view, so utilizing Civil 3D for documentation is not a feasible option; You are only able to import the IMX to show on plans and in model space. Although, you can use Civil 3D as the "middleman" for bringing an IMX into a DWG, then into Navisworks to run clashes. Here is an Autodesk demo that show how you can utilize the Model Coordination module inside ACC to perform clash detection: Clash Detection Process (IMX to DWG to ACC)

To bring in the IMX, go to the InfraWorks tab > Import IMX:
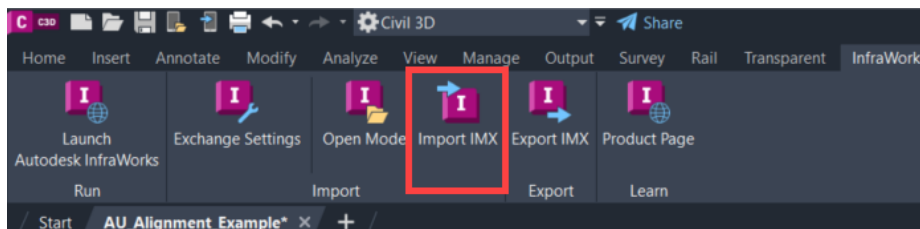
Note, make sure coordinate systems align if you already have the Civil 3D model created.

Notice, there is not "Check for Updates." This feature is not available in Civil 3D. Layers and objects are brought over as disconnected / exploded elements.
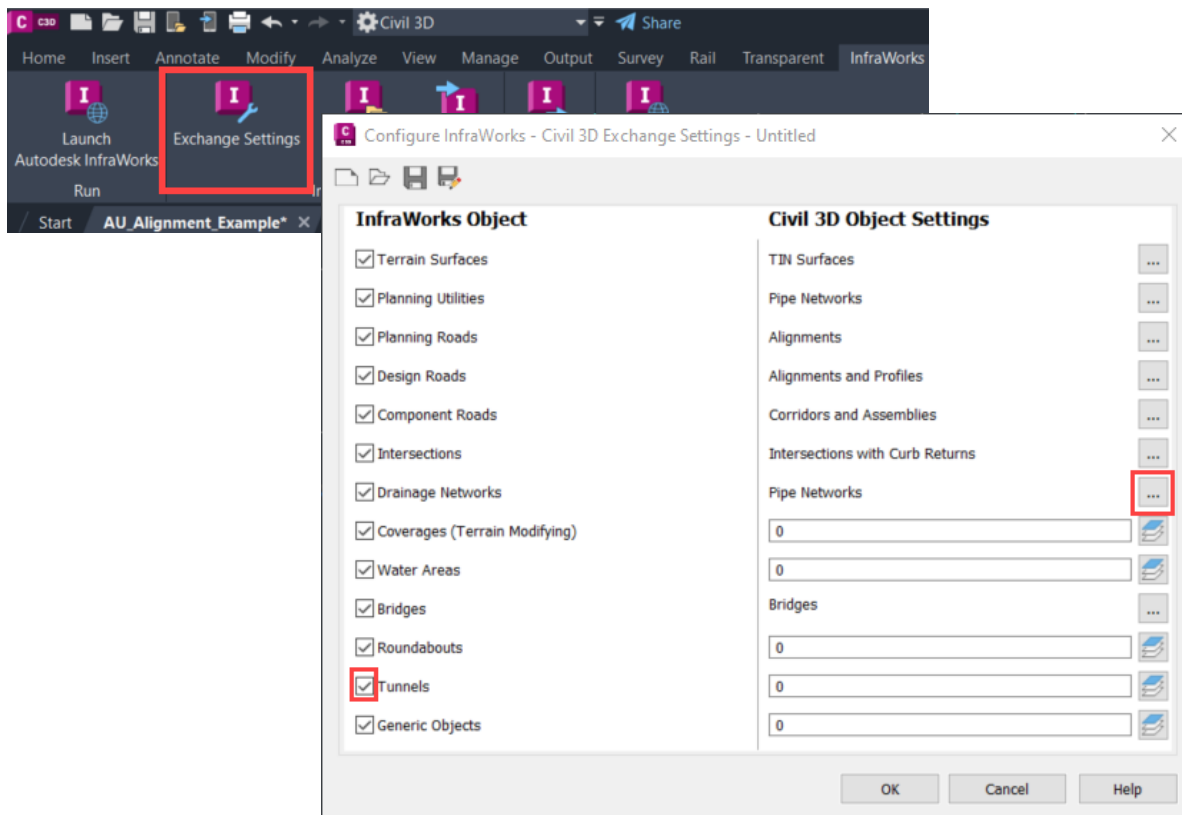
To edit what objects are brought into Civil 3D, select Exchange Settings, and check the boxes on the left side. (Shown on previous page) To edit how Civil 3D objects are recognized when brought into InfraWorks, select the three dots for each element category, shown on previous page, then adjust settings:
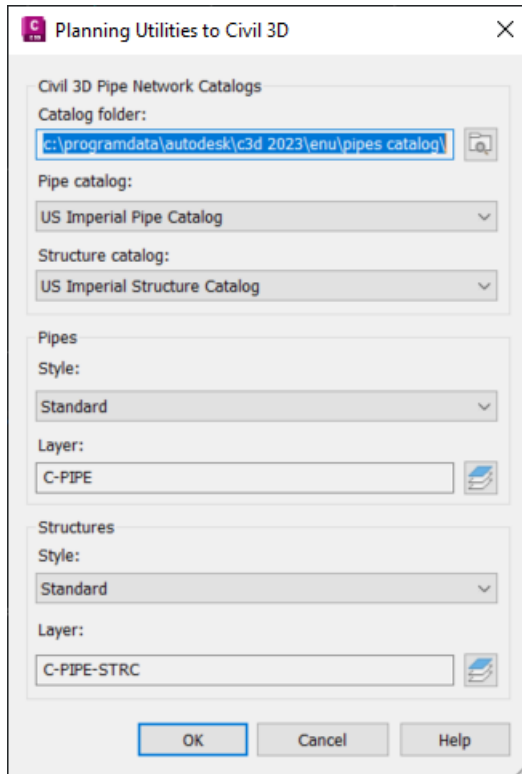
Learning Objective 3 – HNTB Lessons Learned

Assessment of Integration Workflows | With InfraWorks

Since the ability to design and integrate civil structures is fairly new, there are some limitations with the workflow. The limitations listed below are items we believe would greatly improve both modeling and documentation. Note, many of these limitations will no longer exist with the next InfraWorks release! (See learning Objective 4)

Limitations | Translation to Revit

1. You cannot modify Civil Structure geometry once it has been brought into Revit. For example, cutting voids or joining Revit geometry with imported civil structure geometry is not currently an option.

2. Category Mapping is limited to generic models for tunnels, which limits visibility graphics control and prevents accurate category assignment best practice.

3. Limited Type Parameter control. With the type parameter "grayed out", you can't generate type parameters such as keynote tags or utilize interoperability tools to push UniFormat / Master Format classification codes to civil structures.

4. Station offset labeling is not available. You are only able to add station labels and Northing and Easting notation along the alignment.

Limitation | InfraWorks Modeling

1. You cannot "check for updates" of an import Inventor part for a tunnel segment in InfraWorks. The feature is "grayed out", which requires you to import a new IPT and swap that tunnel segment, removing all manually placed cross sections.

2. Inventor learning curve. Tunnel designer needs to be proficient in both InfraWorks and Inventor for this workflow to be efficient. (Complex geometry in Inventor requires a good understanding of formulas, equations, assemblies, iLogic, etc.)

3. Cannot place an alignment on top of another alignment in InfraWorks.

4. Placement of objects must be relative to an alignment. You are not able to associate InfraWorks generic models based on other geometry or parameters within that geometry.

5. Visibility of Tunnel within cross section view. When you go to the cross-section viewer in InfraWorks, you can only toggle features such as roads, topography, and drainage.

6. Cannot change material of slice-based geometry in InfraWorks. This would need to be added as a shared parameter on the revit side. (Due to locked type parameters)

Assessment of Integration Workflows | Without InfraWorks

We also investigated some alternative options for tunnel modeling that do not involve the use of InfraWorks or Inventor. These workflows have some disadvantages and pre-requisites, namely requiring a strong programming background and mindset. Here is an overview of each workflow along with our finding, but we encourage you to investigate further based on your project needs.

Connected Workflow (presented at AU 2019)

This process involves extracting excel data from a Civil 3D corridor to duplicate into revit as geometry & Dynamo scripting to update models via feature lines and point codes, connecting Civil3D subassemblies. Corridor reporting is then used to generate and Excel sheet of northing and easting coordinates by station. Dynamo was then used to generate linear and point geometry from the Excel data, as well as to create the Revit geometry itself.

More info: [Connected Bridge Design | Autodesk University 2019](#)

CivilConnection "Linear Structures Workflow"

In this workflow, data is exchanged using custom Dynamo nodes and graphs. It is available as a github project that contains the source code itself as well as the compiled Dynamo nodes. This workflow utilizes subassembly shapes from a Civil 3D corridor to generate lofted geometry in Revit. This workflow can also utilize an IFC-based workflow where corridor solids are created in Civil3D and then linked to Revit via an IFC export.

A disadvantage, for both the Connected Workflow and CivilConnection, scripts developed for one project likely won't translate to another given the nuances within the code and varying Civil 3D sub-assemblies between tunnel types. For example, say a design iteration occurs to the tunnel cross section; updating may require recreating point codes / sub-assemblies and rewriting scripts, rather than updating an Inventor part and simply 'checking for updates' in InfraWorks.

More info: [Linear Structures Workflow Guide](#)

Speckle Connectors

This platform does open-source data sharing at the object (not file) level. They have developed a plug-in for various design apps, that utilize a cloud based central model for translating data and can be synced between software. Speckle connectors are fairly new and still need some work to be utilized as a dynamic link between Civil 3D and Revit. Some issues we found include: cannot map categories in revit, cannot setup Shared Coordinates, and mixed results with 3D appearance when updating / syncing. Speckle aims to be the "git" of AEC and uses workflows from software development such as branches and commits. It reads binary data from multiple software packages such as Revit, AutoCAD, Blender, and Rhino and serializes it to a neutral representation that can be exchanged via API as JSON or stored in a database.

More info: https://speckle.systems/

Learning Objective 4 – Product Road Map & New Features

Learn what's new and what's next: the future of InfraWorks for tunnels.

During the in person live demo we will review these new features:
- **Clipping Planes**
- **Revit Families as Civil Structure Content**
- **Revit Category Mapping for Inventor Parts**
- **Enhanced geometry control for piers and abutments**

For more information and to keep updated with all things InfraWorks, here is a link to the Autodesk product page: InfraWorks Product, Capabilities, and Features