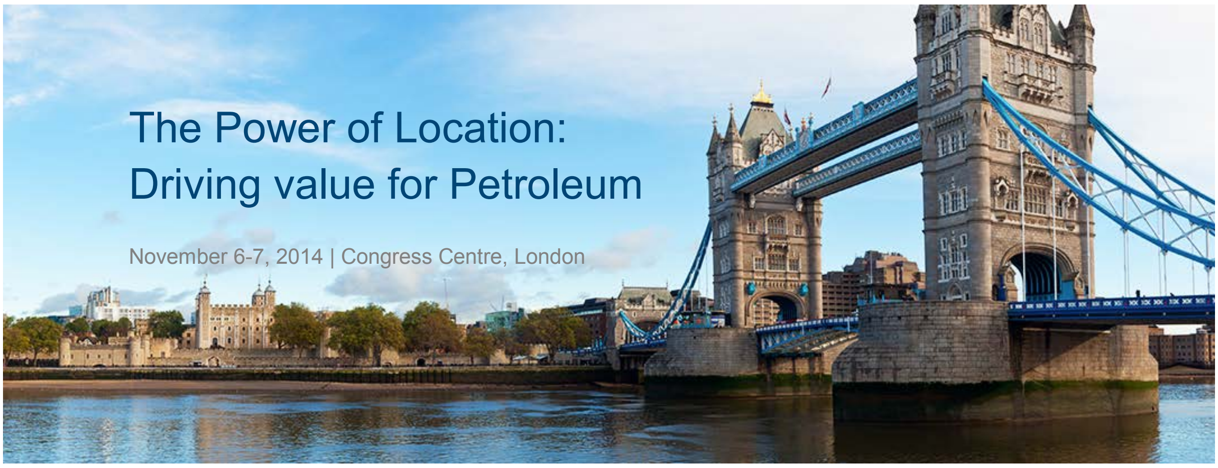

Developing Advanced Engineering Geographical Information Systems for Pipelines

Keith Winning
Principal Pipeline & Geomatics Engineer, CB&I

Esri European Petroleum User Conference 2014
Congress Centre, London 6th – 7th November

Developing Advanced Engineering Geographical Information Systems for Pipelines

Keith Winning – Principal Pipeline & Geomatics Engineer, CB&I

Abstract The use of geographical information systems for pipeline integrity management is well established and growing due to increasing legislative requirements. Pipeline specific GIS database schemas, such as the Pipeline Open Data Standard (PODS) and the ArcGIS Pipeline Data Model (APDM) are enabling operators to better manage their assets. The challenge now is to move towards CAD/GIS integration (CGI), to develop a solution to enable these systems to be used throughout the project life cycle, from conceptual design to operation. Key to this is, are the issues of data interoperability and moving from data rich to information rich environments.

This paper provides an overview of the development of an advanced engineering geographical information system (AEGIS) for pipelines. The term is defined, as are the functional requirements for the system. The key challenges of data interoperability and multi-disciplinary input are explored and a solution discussed. Finally, some examples of the uses of the system during the design phase of the project are presented.

Keywords GIS/CAD Integration • Pipeline Design • Data Interoperability • PODS

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Preface

This paper is based on research carried out as part of a PhD thesis titled: *'Advanced Engineering Geographical Information Systems for Pipelines'*, due for submission in 2015.

The presentation slides are attached at the end of this paper.

Glossary

AEGIS	Advanced Engineering Geographical Information System
APDM	ArcGIS Pipeline Data Model
ASME	American Society of Mechanical Engineers
CAD	Computer Aided Design
CGI	CAD/GIS Integration
GIS	Geographical Information System
OOP	Object Orientated Programming
PIM	Pipeline Integrity Management
PODS	Pipeline Open Data Standard

1. Introduction

The use of geographical information systems (GIS) for pipeline integrity management (PIM) of operational pipelines is well established and growing, in part due to increasing legislative requirements (Perich et al., 2003). The use of GIS for pipelines is underpinned by the development and use of specific GIS database schemas, such as the Pipeline Open Data Standard (PODS) and the ArcGIS Pipeline Data Model (APDM). While the application of GIS for pipeline design is widespread, it is one of a number of disparate systems used during the design phase of the project; systems that frequently rely on the use of subsets of common design data in different formats.

Clearly, not all systems can be integrated into a single solution due to their functional or user requirements. However, where there is sufficient synergy between systems this integrated approach will reduce data interoperability issues and cost.

This paper focuses on the challenge of CAD/GIS integration (CGI) through the development of an advanced engineering geographical information system (AEGIS) for pipelines. It provides an overview of the functional requirements, key issues in the development, and some of the core components of the system.

In 2004, Bill Miller from ESRI stated:

> *"There used to be a huge gap between CAD and GIS … But now it's probably more of a collision zone than a gap."*
>
> *(Miller, 2004)*

While progress has been made, largely through the ability of systems to directly read other proprietary file formats, ten years on from that statement there is much still to do. The challenge now, is to come through this collision zone with improved solutions offering better integration between CAD and GIS.

2. Putting the AE into GIS

The term, Advanced Engineering Geographical Information System (AEGIS) first appeared in the glossary of a standard Geographical Information System (GIS) text (Longley et al., 2010). While Longley et al. introduced the term, they did not define it and it is interesting to note that although it appears in the glossary it is not mentioned elsewhere in the text. In addition, the term AEGIS fails to return anything in internet search engines or online journals, which would suggest that perhaps the authors saw this as an aspirational future direction for GIS, challenging engineers to see the potential for the application of GIS within their own fields.

2.1 Definition and Requirements

Since all GIS systems are designed to store, manage, retrieve and perform queries on geospatial data, an engineering GIS would need to do this with geospatial engineering data. However, to be 'advanced' it must be more than merely a repository for geospatial engineering data; indeed it must be capable of performing analytical and decision making functions within an engineering context whilst presenting the engineer with all the geospatial tools and functionality inherent in a GIS system. The system must provide the following functionality as a minimum:

- All the standard GIS functionality for geospatial data management, access, querying and analysis.
- A method of handling engineering data, including revision and versioning control of datasets.
- Provide specialist engineering geospatial and non-geospatial tools that are specific to the particular field of engineering, within the GIS environment.
- Reduce the interfaces between processes and provide data interoperability.

Based on these requirements, an AEGIS may therefore be defined as:

A single multi-discipline integrated system using an open industry standard schema providing all the standard GIS tools with the added functionality required to undertake the engineering and design of a specific engineering function.

The key component of this definition is that the system should be function and not discipline or software specific.

2.2 Overview

The solution to CGI lies not in the development of complex hybrid systems attempting to provide all the functionality for both CAD and GIS; it is the ability for these different systems to access and share common data that is the goal. This premise is central to the design of the system.

The system is built on an industry standard database schema, in this case PODS with additional tables stored in a new sub-model. This approach ensures that the modifications conform to the compliance rules of the schema. Both the PODS and the APDM schemas were initially designed to store data for the management of operational pipelines, and therefore lack the tables required to store design data. This is addressed through the use of a new sub-model containing the tables required for the design phase of the pipeline.

The underlying object orientated programming (OOP) structure including inheritance, abstract and feature classes, and the modifications to the PODS database schema were covered in more detail in a paper delivered at the PODS User Conference (Winning, 2014b).

2.3 CAD/GIS Integration

One of the major challenges facing the development of an AEGIS, particularly for the design phase of the project is that of data interoperability. This is due to the number of different systems used during this phase of the project. Interoperability may be defined as:

> *"The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units."*
>
> *(BS ISO/IEC 2382-1, 1993)*

In addition to the problems associated with data interoperability, it has a cost impact.

> *"The lack of interoperability between CAD and GIS platforms results in inefficiency and increased costs."*
>
> *(Akinci et al., 2010: 219)*

While the costs associated with poor data interoperability within pipeline engineering are not available, the cost to the U.S. capital facilities industry in 2002 was estimated to be $15.8 billion per year (NIST, 2004: 6-1).

Pipeline design requires the use of a variety of specialist software systems, spanning engineering, design and GIS, which has led to the issues of interoperability between the disparate systems (Akin, 2010: 56). While the systems themselves do not necessarily need to be interoperable, the data that these systems use is frequently common, though stored in different formats; in order to share this information across the systems, data interoperability is required.

> *"Complex behaviours, however, such as linear referencing for service laterals, and pipe material and size combinations are much more esoteric and are often lost in translation or interoperation efforts."*
>
> *(Casey & Vankadara, 2010: 151)*

At the most basic level this is achieved by syntactic interoperability, through specified data formats and communication protocols (Ouksel & Sheth, 1999: 5). Semantic interoperability builds on the syntactic by providing an ability to automatically exchange data without loss or corruption, ensuring meaningful exchange between systems (Heiler, 1995: 271). While semantic interoperability is seen as the goal at present the method outlined in this paper is based on syntactic interoperability.

It is also important to understand that users may be reluctant to master new technology and that sometimes what can be perceived as an issue of interoperability may in fact be due to the hesitancy of users to change the way that they work (Miller, 2004). Both the ease of use and the issues of integration need to be addressed.

> *"Besides agreement on specifications and standards, the next generation of GIS software and tools will be developed based on the concept of ease of use, implementation, and integration."*
>
> *(Kasccaemsuppakorn et al., 2010: 45)*

2.4 Development

The system is based on a data centric model which is accessible using a variety of systems. This enables the user, rather than the system developer to determine the tools used to manipulate the model. It is also recognising that the efficient design of pipeline projects requires a variety of different design tools.

Central to the development of the system is realising that different stages of the project present different challenges.

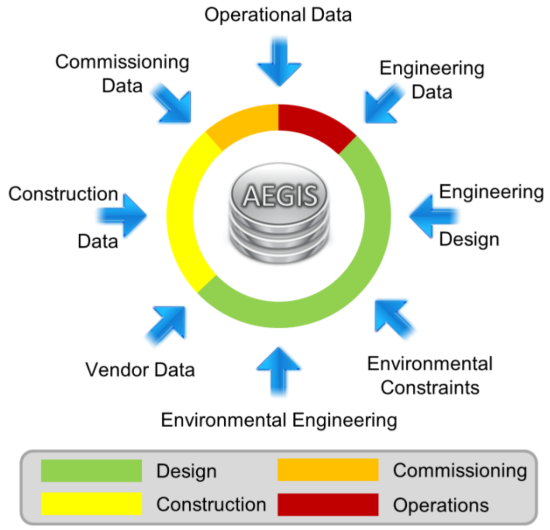

Figure 1 – AEGIS Project Phases

One of the main requirements of the design phase of the project is to produce large numbers of alignment sheets and route maps for the entire route. With an alignment sheet typically covering 1km of pipeline, the number of drawings required for major projects is significant. The choice of engineering design software is based on a number of criteria, including:

- The requirement to handle geospatial data.
- The ability to produce large volumes of complex design drawings.
- The preference and availability of trained users.

In the current model, AutoCAD Map™ was selected as the selected engineering design geospatial software.

The modified PODS schema was made available to AutoCAD either by linking directly to the ArcSDE server or by storing the data within a single model drawing. The second option can be useful where the users knowledge of database handling with the AutoCAD environment is a constraint or for small projects not wanting to incur the overhead and costs of ArcSDE. In this case the tabular data is stored as extended entity data.

The interface, both CAD and GIS provides access to the additional AEGIS functionality through a functionally structured system of toolbars and menus. The only exception to this approach is the tools for the production of the alignment sheets which is only accessible through the CAD system. Although it requires the recoding of the system to enable tools to be available through both systems, this is central to enabling the user to determine the software tools to use.

2.5 System Components

An overview of the system, identifying the users and related functions is presented as a use case diagram.

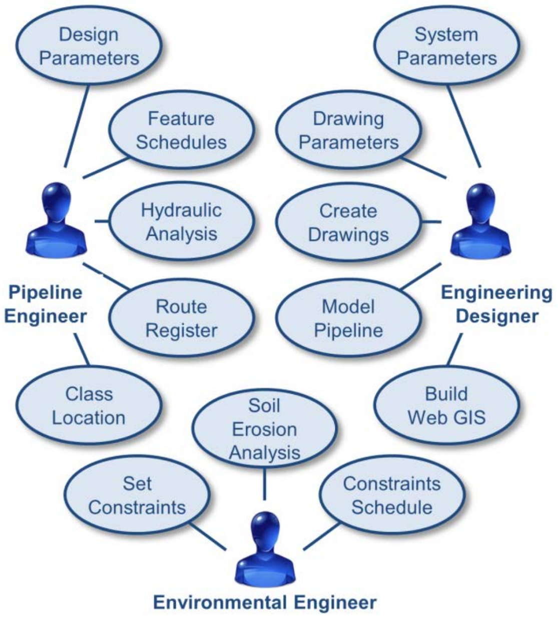

Figure 2 – AEGIS Use Case Diagram

The components of the system discussed in this paper have been selected to demonstrate the application of:

- Geospatial analysis to determine engineering code requirements. (Wall thickness requirements due to population - ASME B31.8).
- GIS to perform engineering analysis. (Preliminary hydraulic analysis of pipeline routes within GIS).
- Multi-disciplinary approach. (Soil erosion risk assessment using remote sensed data).
- CAD/GIS integration. (Production of alignment sheets).

2.5.1 Class Location

For gas transmission pipelines, the design factor is in part defined by code requirements according to the population density within the proximity of the pipeline. This forms the basis for the minimum wall thickness at any given location along the pipeline. While the wall thickness can and will be increased due to engineering constraints, it cannot be reduced below the minimum code requirements. There are a number of different codes which identify the design factor requirements; in this case the American standard ASME B31.8.

This requires determining the number of properties with human occupancy within a ¼ of a mile buffer centered on the pipeline. Traditionally this has been carried out by engineers using alignment sheets of the pipeline route; an iterative and time consuming method which needs to be carried every time the route changes. This type of analysis is ideally suited to the geospatial tools inherent in GIS.

While this has been fairly straight forward to code, the benefits of this approach have enabled the code requirements to be identified accurately. This information is shown on the alignment sheets as well as forming the basis for the heavy wall allocation report and hydrotest requirements.

2.5.2 Hydraulic Analysis

This is one of the major determinates of the route selection process; it presents challenges due to the computational effort and data interoperability issues.

In order to incorporate hydraulic modelling into the GIS model the major challenge was the computational efficiency, as hydraulic analysis requires a very large number of iterative implicit calculations to establish the frictional pressure loss within the system. There are a number of explicit equations for the approximation of the friction factor and there have been a number of reviews. However, the previous reviews were lacking insofar as they were based on differing boundary conditions and either did not consider the computational efficiency, or did so by notational key strokes or statistical methods. Based on this comprehensive review (Winning & Coole, 2013) a new computationally efficient explicit method for estimating the friction factor was developed (Winning & Coole, 2014) which forms the basis of the method employed in the GIS model.

This tool enables the preliminary sizing and pump/compressor station requirements of the pipeline to be conducted quickly. In addition, it enables the route selection process to consider the hydraulic requirements in addition to the other geospatial constraints.

2.5.3 Soil Erosion Risk Assessment

The effects of soil loss worldwide are a major concern; it impacts on the environment, food security and public health (Bandara et al., 2001; Pimentel, 2006). It is estimated that 75 billion metric tons of soil worldwide are lost per annum, with Africa, Asia and South America typically experiencing average losses of 30 to 40 tons per hectare per annum (t ha^{-1} year^{-1}) (Pimentel et al., 1995).

> *"On the basis of its temporal and spatial ubiquity, erosion qualifies as a major, quite possibly the major, environmental problem worldwide."*
>
> *(Toy et al., 2002: 2)*

By utilising GIS and public domain remote sensed data it is possible to perform a preliminary soil erosion risk analysis aggregated into 1000m sections for onshore pipeline corridors. The results obtained using this method corresponded well with the soil erosion risk assessment carried out in the field.

The areas where this method fails to correctly classify the soil erosion risk are largely confined to major river crossings and areas of seismic activity, which would require field verification irrespective of the results obtained for these sections using this method. Using this method it is possible to identify areas along the pipeline corridor where there is potential for soil erosion risk early on in the project design; this enables the route selection process to consider this important environmental aspect, as well as providing a basis for focusing any subsequent field investigation. The proposed method enables the erosion risk to be quickly reassessed for comparison of different route options or for revisions to the proposed pipeline route.

This component of the AEGIS was presented in more detail at the ESRI European User Conference (Winning, 2014a), based on the paper in Biosystems Engineering (Winning & Hann, 2014).

2.5.4 Drawing Production

The alignment sheets are created through Visual LISP™ (VLX) code, resulting in high quality drawings produced with considerable savings in drafting time. Once produced these drawings are checked and issued; at these fixed maturity levels the data is extracted from the database through VLX code to tab delimitated files. These files directly replicate the PODS table and attribute structure, with all GUID's and relationships being created at this stage. This part of the process takes under two minutes for a pipeline route of over 450km (Figure 3).

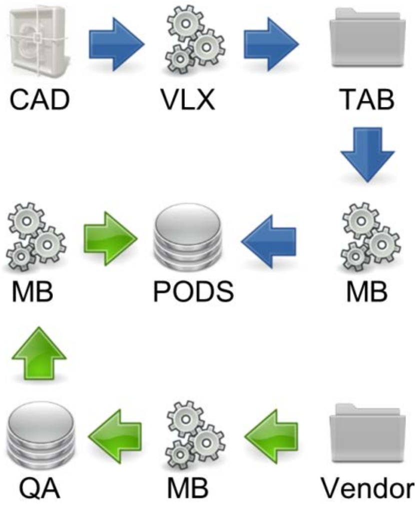

Figure 3 – Importing Design and Vendor Data

The tab delimitated files can be viewed and checked externally to verify and validate the VLX code. These files are then used by an ESRI Model Builder script to populate the PODS model. The model then provides the data for the webGIS to deliver the data to the project stakeholders; this entire process is achieved in a few hours.

This is shown in the second part of Figure 3. The vendor is issued with data templates in Excel™; these templates identify all the PODS attributes required, irrespective of the table that they reside in, thereby simplifying the process for the vendor. The attribute data dictionary entries for the required attributes are also given in a separate worksheet to aid the vendor. Finally, the templates contain some Visual Basic for Applications™ (VBA) macros which the vendor can run in order to check for missing data or incorrect data types, prior to submission.

These spreadsheets are then processed using ESRI Model Builder scripts to verify the data integrity; if the data is good, GUID's are created and the data output to a holding database for further QA/QC. Once final checking is complete, the data is imported into the PODS database using an ESRI Model Builder script. It should be noted that at this stage no geometry is created from the vendor data.

In a similar method used for the gathering of vendor data, the pipeline installation contractor is supplied a number of Excel™ spreadsheets as templates for collecting, submitting and verifying the as built data prior to submission.

The files are then checked using VBA code and if accepted GUID's are added to those items where there is not a corresponding vendor GUID, such as CP test post or pipeline marker. These files are then converted to tab delimitated files with the PODS table and attribute structure, allowing validation of the VBA code. These files are then used by an ESRI Model Builder script to import the data into the model, adding the required relationships to the vendor data (Figure 4).

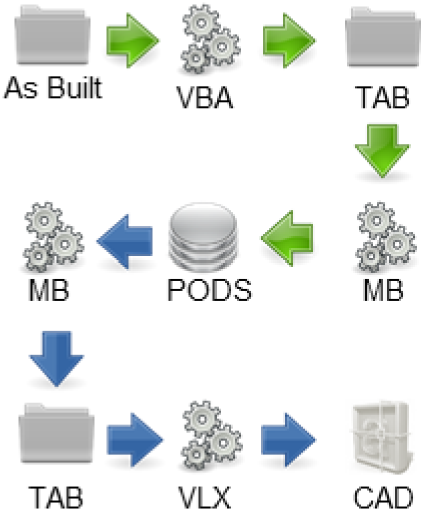

Figure 4 – As-Built PODS Model Validation

In order to validate the final model, the data is extracted using ESRI Model Builder scripts to generate the tab delimitated files. These files are then used by VLX code to create a CAD model of the PODS model.

Form the CAD model, using the same VLX code used to generate the design alignment sheets, drawings are automatically created which are then reviewed against the contractor supplied red line mark ups.

2.5.5 Web Services

A crucial component of the system is the ability to disseminate information across the project stakeholders, accurately and quickly. The obvious platform for this is the web, with the ArcGIS web services. This is facilitated by the creation of ArcGIS model builder scripts to import CAD model data into the PODS format, enabling the issued design to be disseminated across the wider project team without delay.

3. Conclusions

The solution presented is data centric, software independent and based on an industry standard schema; it is also function rather than discipline specific. This approach improves data interoperability and reduces the number of discipline interfaces. By exposing the core geospatial components in both the GIS and CAD platforms, users are able to access and analyse the data using the software tools of their choice, further reducing interoperability issues.

While a structured database schema is important, the use of an industry standard schema with compliant modifications allows the data to be shared across organisations as required by the pipeline operator. Given that pipeline operators frequently use different engineering consultants for the various phases of the pipeline project, this provides significant cost and schedule savings in transferring geospatial engineering data between companies.

Although the aim has been to reduce the number of interfaces, the use of clearly defined programming interfaces between CAD and GIS, recognises that the required skill sets are likely to be distributed across the design team. In line with the requirements of interoperability, these programming interfaces are transparent to the final user.

This approach demonstrates the value of an integrated system for the solving of geospatial engineering problems, such as the determination of class location or for performing high level screening hydraulic analysis of the proposed pipeline route. It also enables the pipeline engineer to help to improve the route definition from an environmental perspective. Central to the system is the concept that the model is the primary deliverable from the design activity rather than the drawings and associated schedules, which are automated outputs from the model.

While the proposed solution does not resolve all the issues facing the pipeline engineer, it does address some of the key issues of CGI and presents an integrated approach focusing on functional requirements.

Keith Winning is a Chartered Engineer, Environmentalist and Geographer. He is a Member of the Institution of Mechanical Engineers and a Fellow of the Institution of Engineering Designers and the Royal Geographical Society.

He has Masters in both Mechanical Engineering and Geographical Information Science and over 25 years' experience in the field of pipeline design. He is currently reading for a PhD in the development of Advanced Engineering Geographical Information Systems for pipeline design, based on the PODS schema.

He is the Lead Pipeline Engineer on a major pipeline project, where he is involved in the development of a PODS based model for the design and construction of a pipeline in Azerbaijan and Georgia, which draws heavily on his current research.

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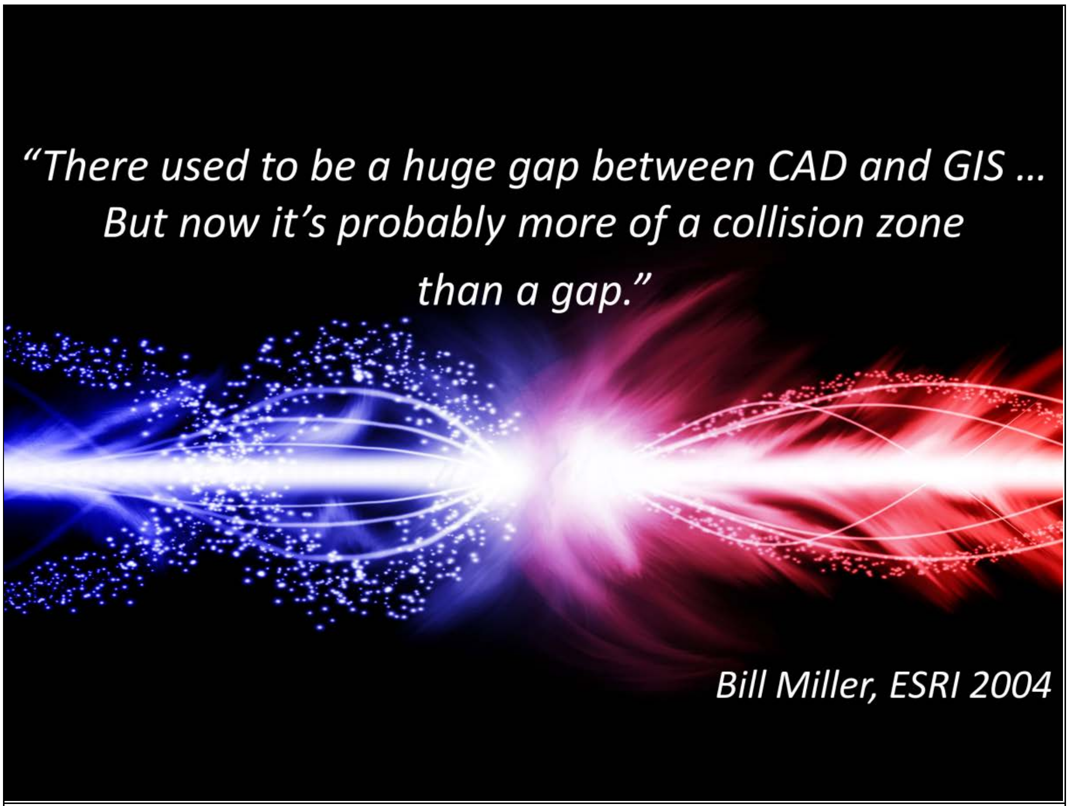
Appendix – Presentation Slides

Developing
Advanced Engineering
Geographical Information Systems
for Pipelines

Keith Winning

Esri European Petroleum GIS Conference 2014
November 6-7, 2014 | Congress Centre, London

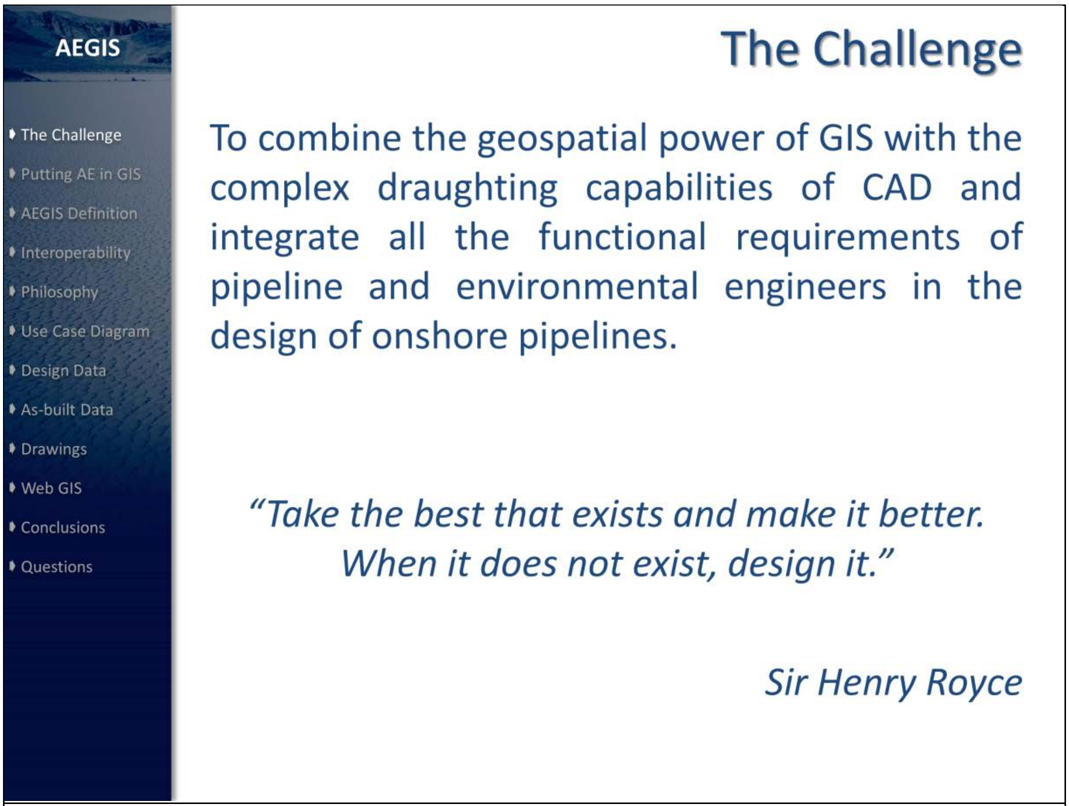
Slide 1



"There used to be a huge gap between CAD and GIS … But now it's probably more of a collision zone than a gap."

Bill Miller, ESRI 2004

Slide 2



AEGIS

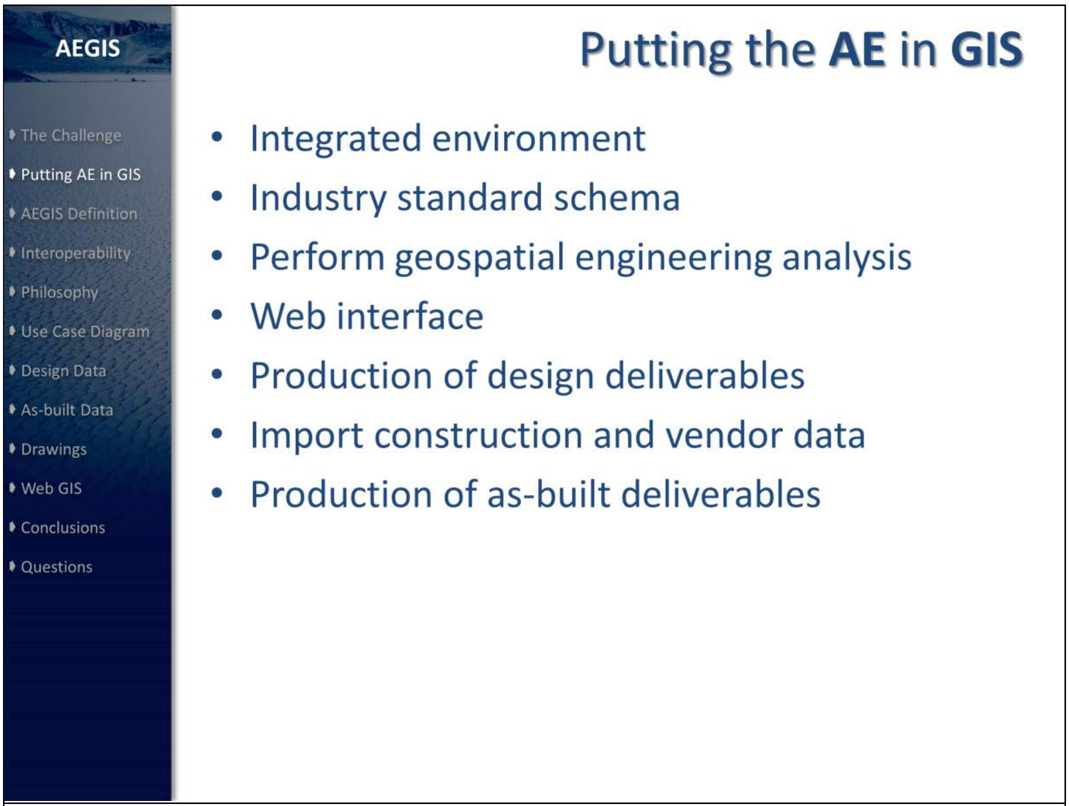
- The Challenge
- Putting AE in GIS
- AEGIS Definition
- Interoperability
- Philosophy
- Use Case Diagram
- Design Data
- As-built Data
- Drawings
- Web GIS
- Conclusions
- Questions

The Challenge

To combine the geospatial power of GIS with the complex draughting capabilities of CAD and integrate all the functional requirements of pipeline and environmental engineers in the design of onshore pipelines.

> *“Take the best that exists and make it better.*
> *When it does not exist, design it.”*
>
> *Sir Henry Royce*

Slide 3



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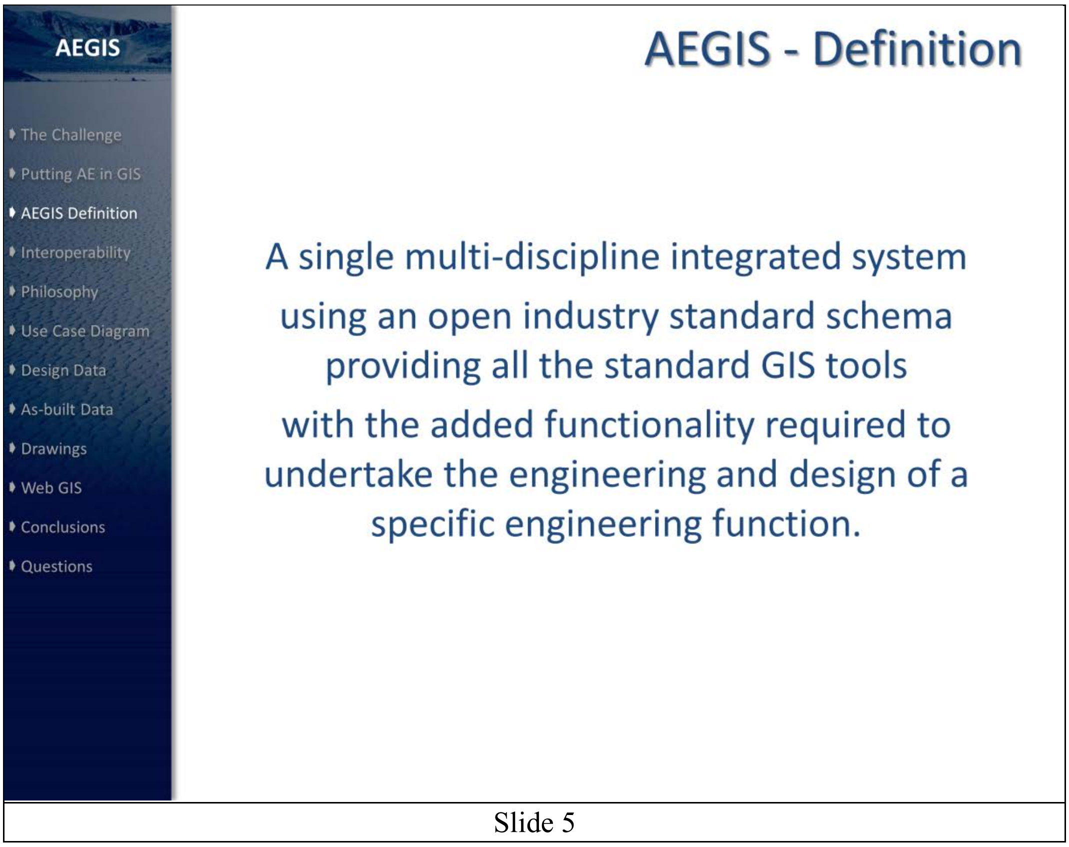
Putting the **AE** in **GIS**

- Integrated environment
- Industry standard schema
- Perform geospatial engineering analysis
- Web interface
- Production of design deliverables
- Import construction and vendor data
- Production of as-built deliverables

Slide 4



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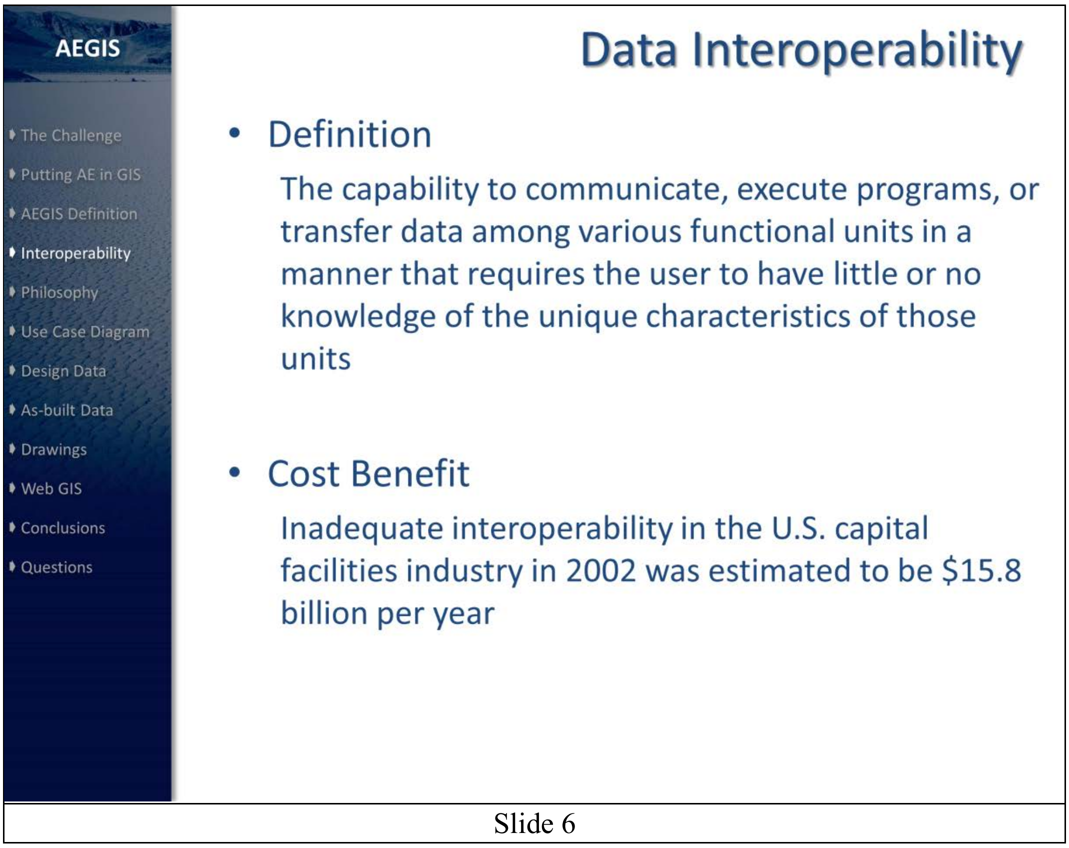
AEGIS - Definition

A single multi-discipline integrated system

using an open industry standard schema providing all the standard GIS tools

with the added functionality required to undertake the engineering and design of a specific engineering function.

Slide 5



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- Questions

Data Interoperability

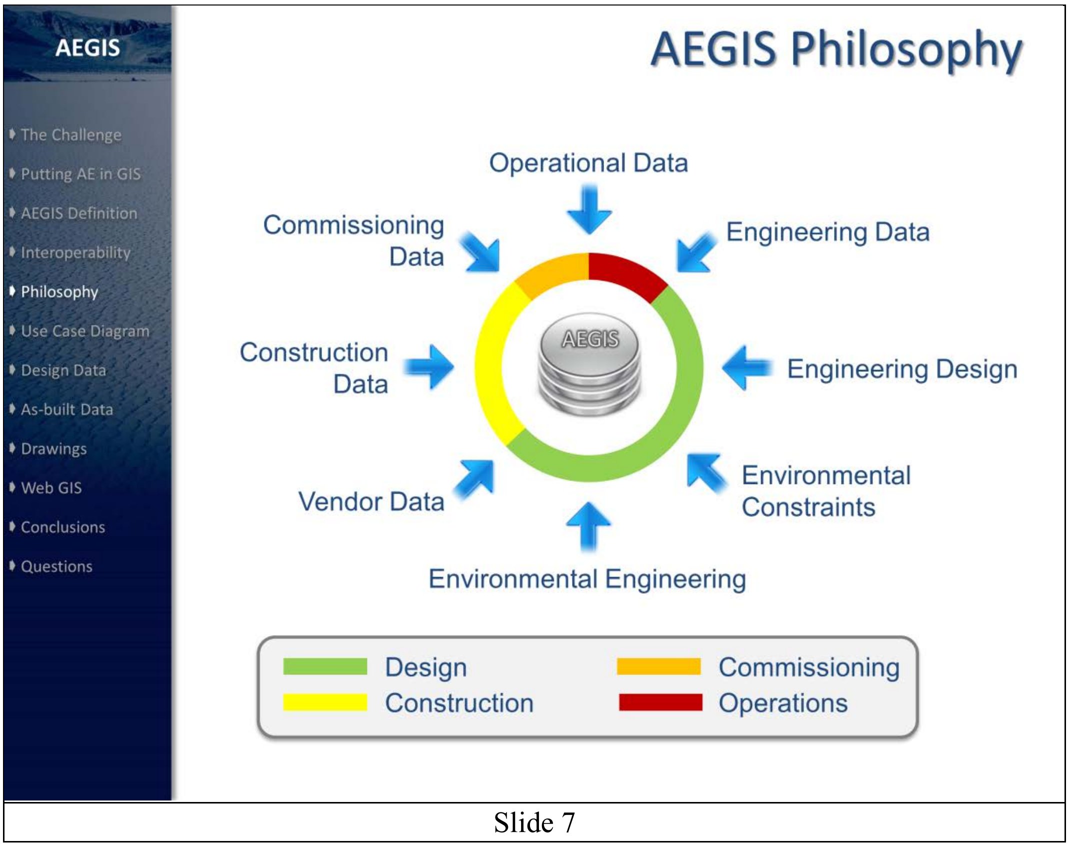
- Definition

  The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

- Cost Benefit

  Inadequate interoperability in the U.S. capital facilities industry in 2002 was estimated to be $15.8 billion per year

Slide 6



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- Questions

AEGIS Philosophy

Operational Data

Engineering Data

Engineering Design

Environmental Constraints

Environmental Engineering

Vendor Data

Construction Data

Commissioning Data

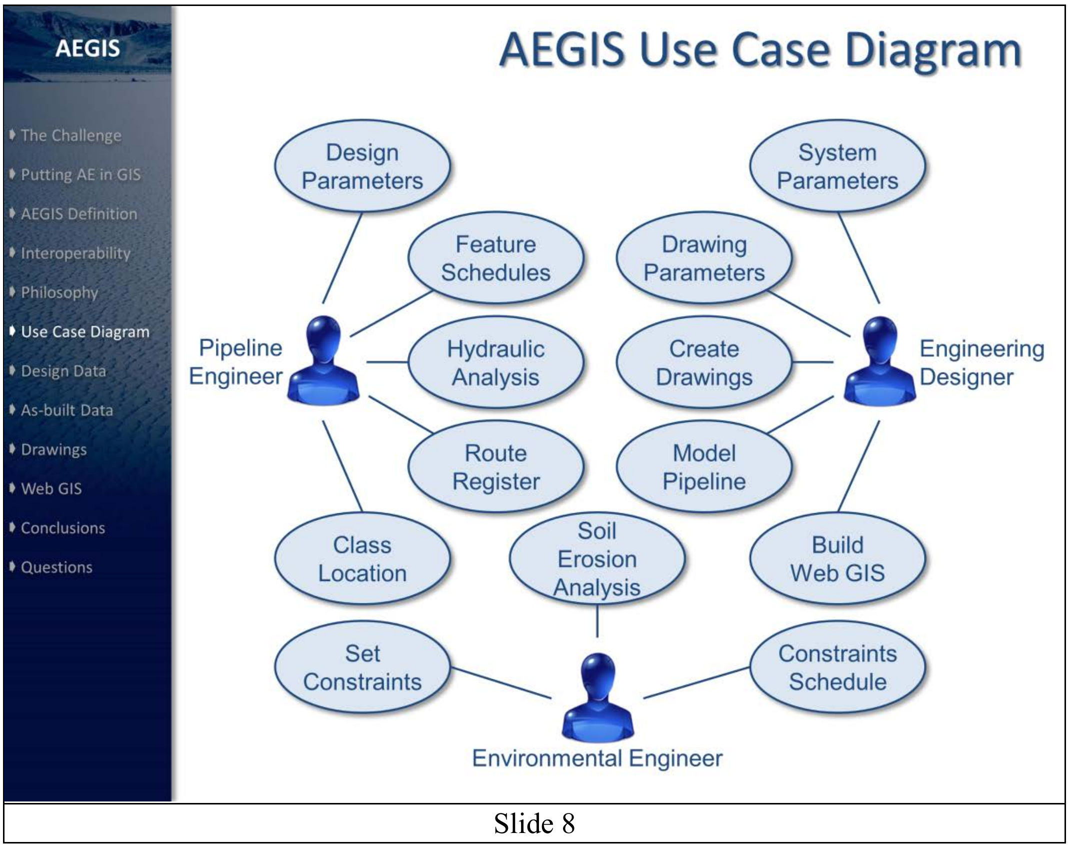
🟩 Design

🟨 Construction

🟧 Commissioning

🟥 Operations

Slide 7



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- Questions

AEGIS Use Case Diagram

Pipeline Engineer

Design Parameters

Feature Schedules

Hydraulic Analysis

Route Register

Class Location

Engineering Designer

System Parameters

Drawing Parameters

Create Drawings

Model Pipeline

Build Web GIS

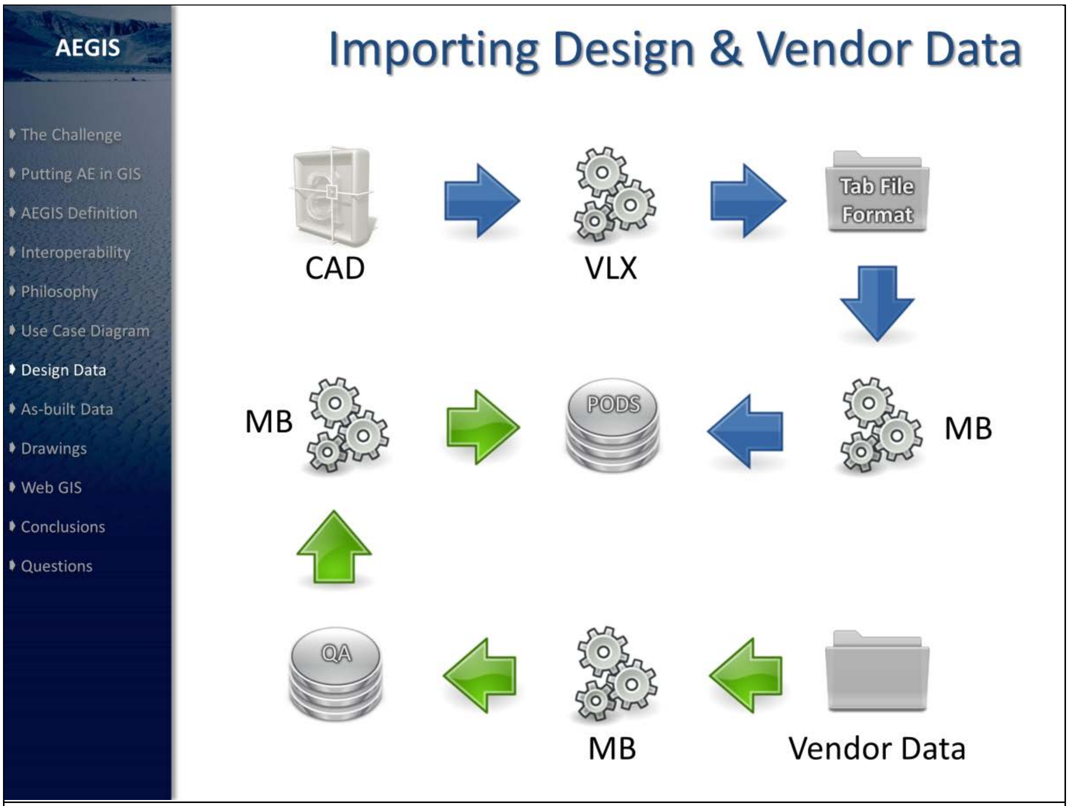
Environmental Engineer

Soil Erosion Analysis

Set Constraints

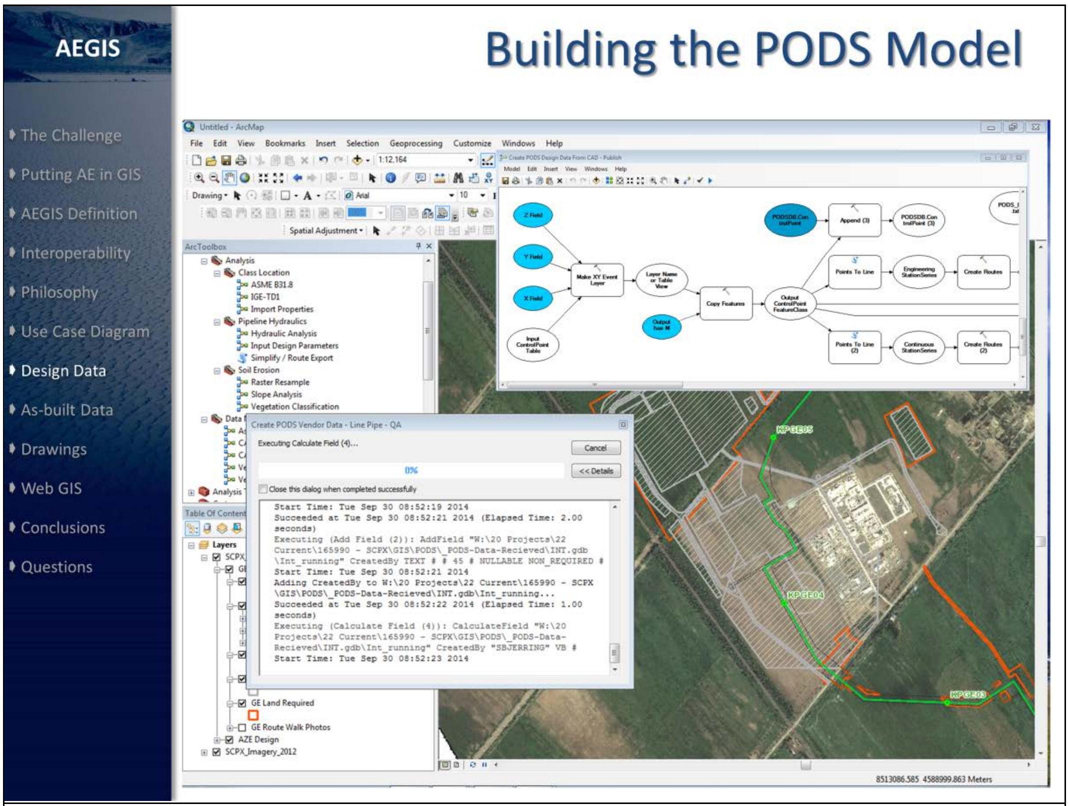
Constraints Schedule

Slide 8



Importing Design & Vendor Data

Slide 9



Building the PODS Model

Create PODS Vendor Data - Line Pipe - QA

Executing Calculate Field (4)...

Cancel

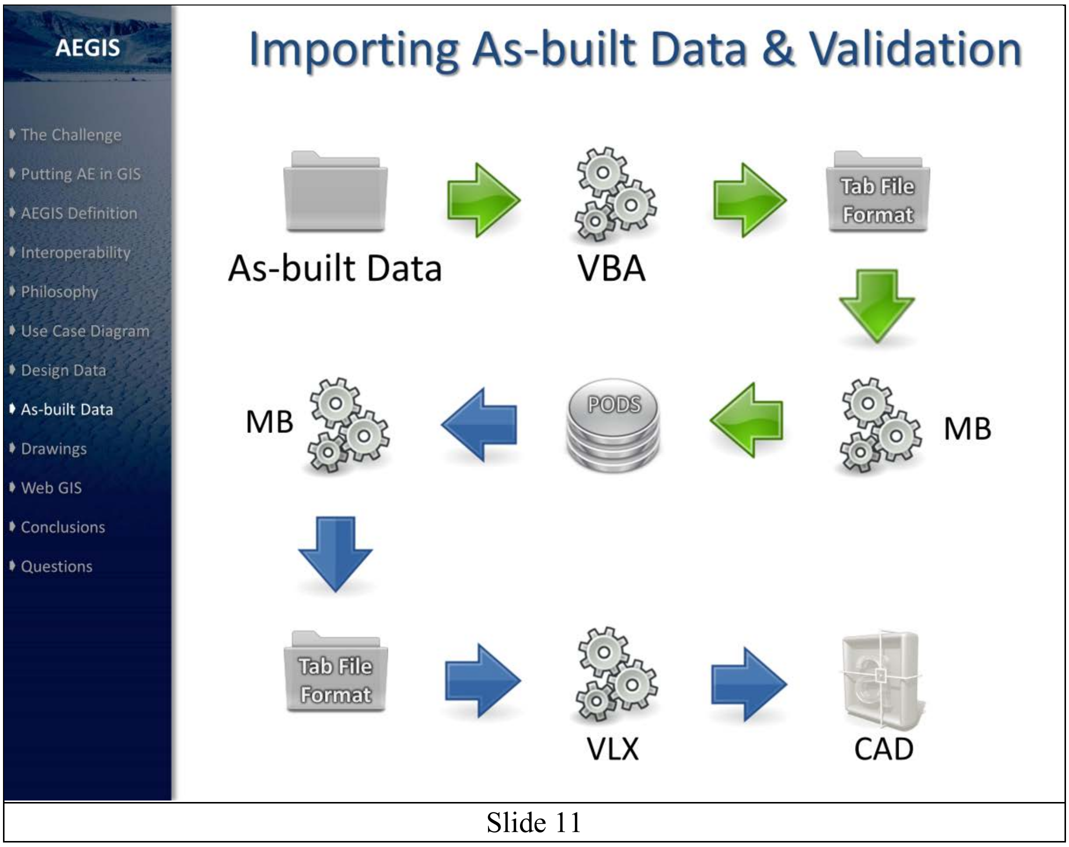
0%

<< Details

☐ Close this dialog when completed successfully

```
Start Time: Tue Sep 30 08:52:19 2014
Succeeded at Tue Sep 30 08:52:21 2014 (Elapsed Time: 2.00
seconds)
Executing (Add Field (2)): AddField "W:\20 Projects\22
Current\165990 - SCPX\GIS\PODS\_PODS-Data-Recieved\INT.gdb
\Int_running" CreatedBy TEXT # # 45 # NULLABLE NON_REQUIRED #
Start Time: Tue Sep 30 08:52:21 2014
Adding CreatedBy to W:\20 Projects\22 Current\165990 - SCPX
\GIS\PODS\_PODS-Data-Recieved\INT.gdb\Int_running...
Succeeded at Tue Sep 30 08:52:22 2014 (Elapsed Time: 1.00
seconds)
Executing (Calculate Field (4)): CalculateField "W:\20
Projects\22 Current\165990 - SCPX\GIS\PODS\_PODS-Data-
Recieved\INT.gdb\Int_running" CreatedBy "SBJERRING" VB #
Start Time: Tue Sep 30 08:52:23 2014
```

Slide 10



AEGIS

- The Challenge
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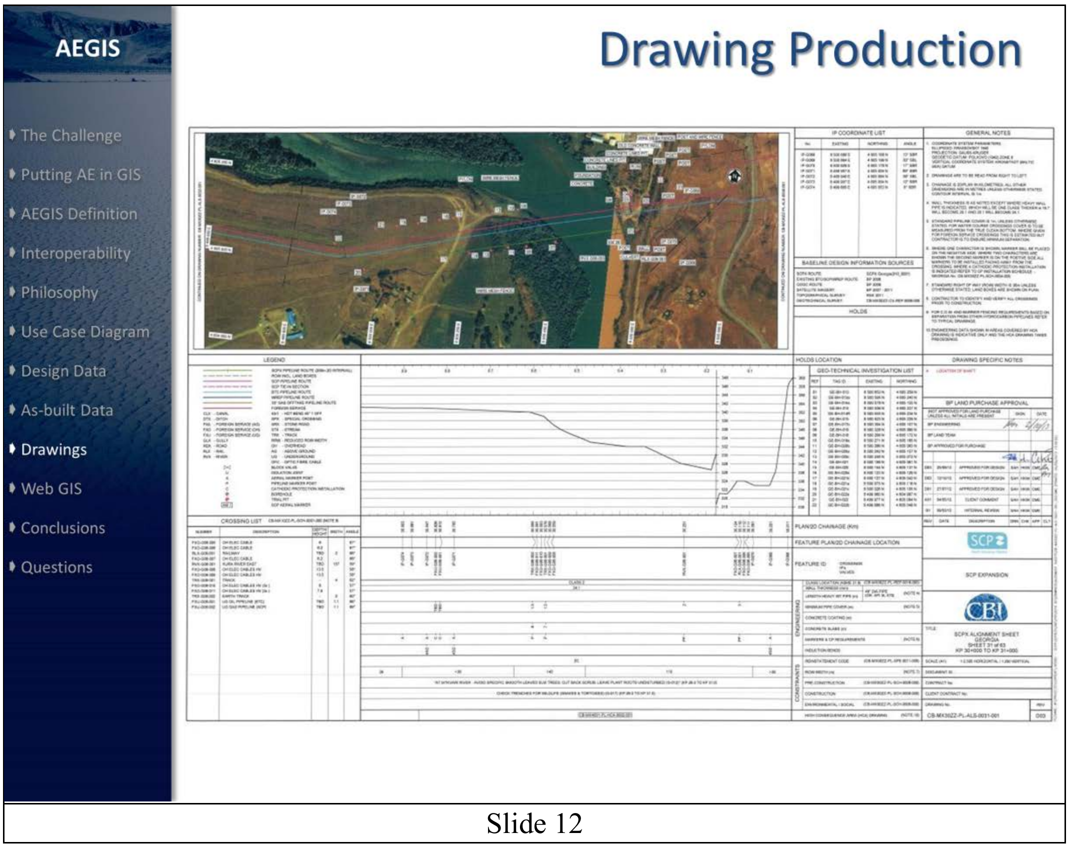
Importing As-built Data & Validation

As-built Data → VBA → Tab File Format → MB → PODS → MB → Tab File Format → VLX → CAD

Slide 11



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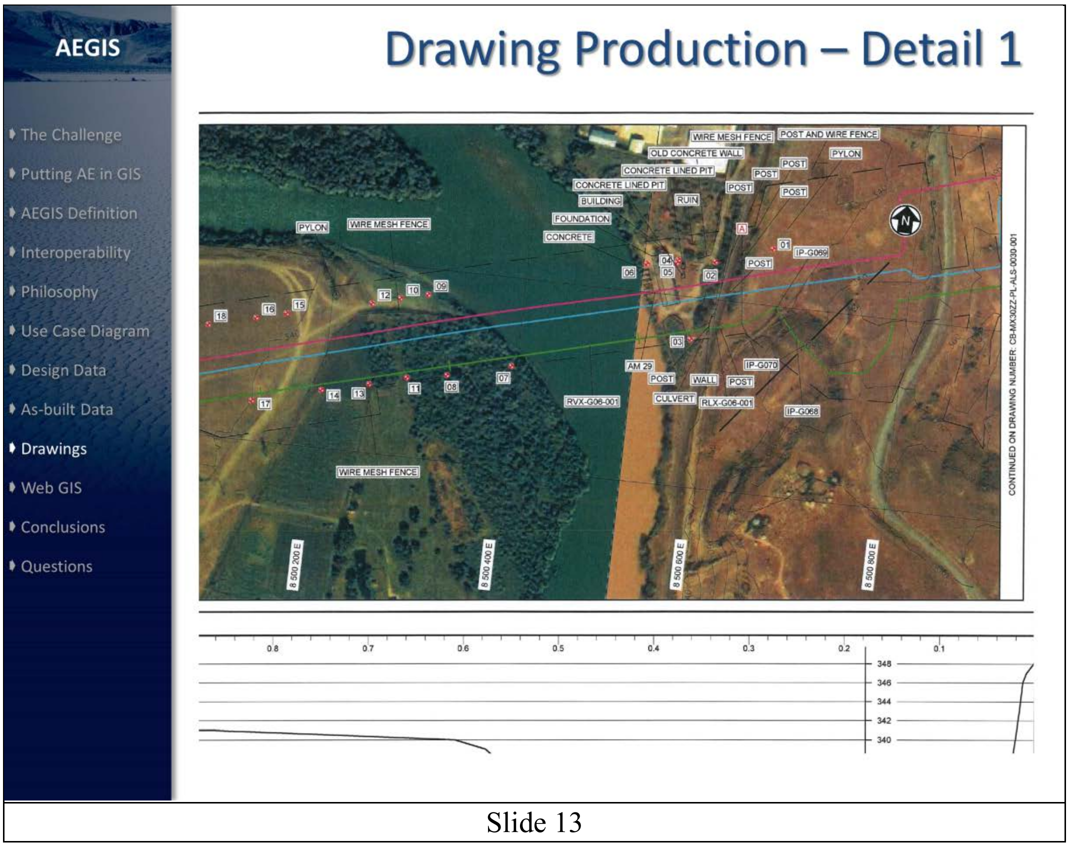
Drawing Production

Slide 12



Drawing Production – Detail 1

AEGIS

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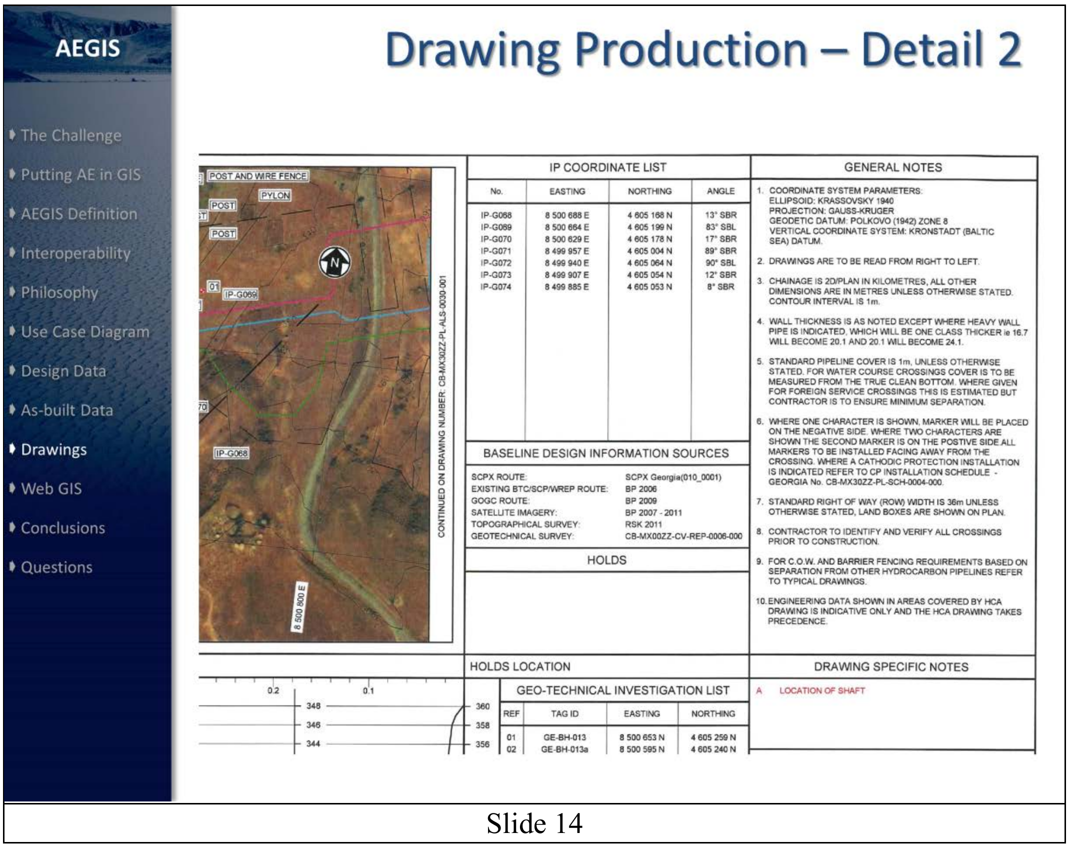
Slide 13



Drawing Production – Detail 2

AEGIS

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IP COORDINATE LIST

No.	EASTING	NORTHING	ANGLE
IP-G068	8 500 688 E	4 605 168 N	13° SBR
IP-G069	8 500 664 E	4 605 199 N	83° SBL
IP-G070	8 500 629 E	4 605 178 N	17° SBR
IP-G071	8 499 957 E	4 605 004 N	89° SBR
IP-G072	8 499 940 E	4 605 064 N	90° SBL
IP-G073	8 499 907 E	4 605 054 N	12° SBR
IP-G074	8 499 885 E	4 605 053 N	8° SBR

BASELINE DESIGN INFORMATION SOURCES

SCPX ROUTE:	SCPX Georgia(010_0001)
EXISTING BTC/SCP/WREP ROUTE:	BP 2006
GOGC ROUTE:	BP 2009
SATELLITE IMAGERY:	BP 2007 - 2011
TOPOGRAPHICAL SURVEY:	RSK 2011
GEOTECHNICAL SURVEY:	CB-MX00ZZ-CV-REP-0006-000

HOLDS

HOLDS LOCATION

GEO-TECHNICAL INVESTIGATION LIST

REF	TAG ID	EASTING	NORTHING
01	GE-BH-013	8 500 653 N	4 605 259 N
02	GE-BH-013a	8 500 595 N	4 605 240 N

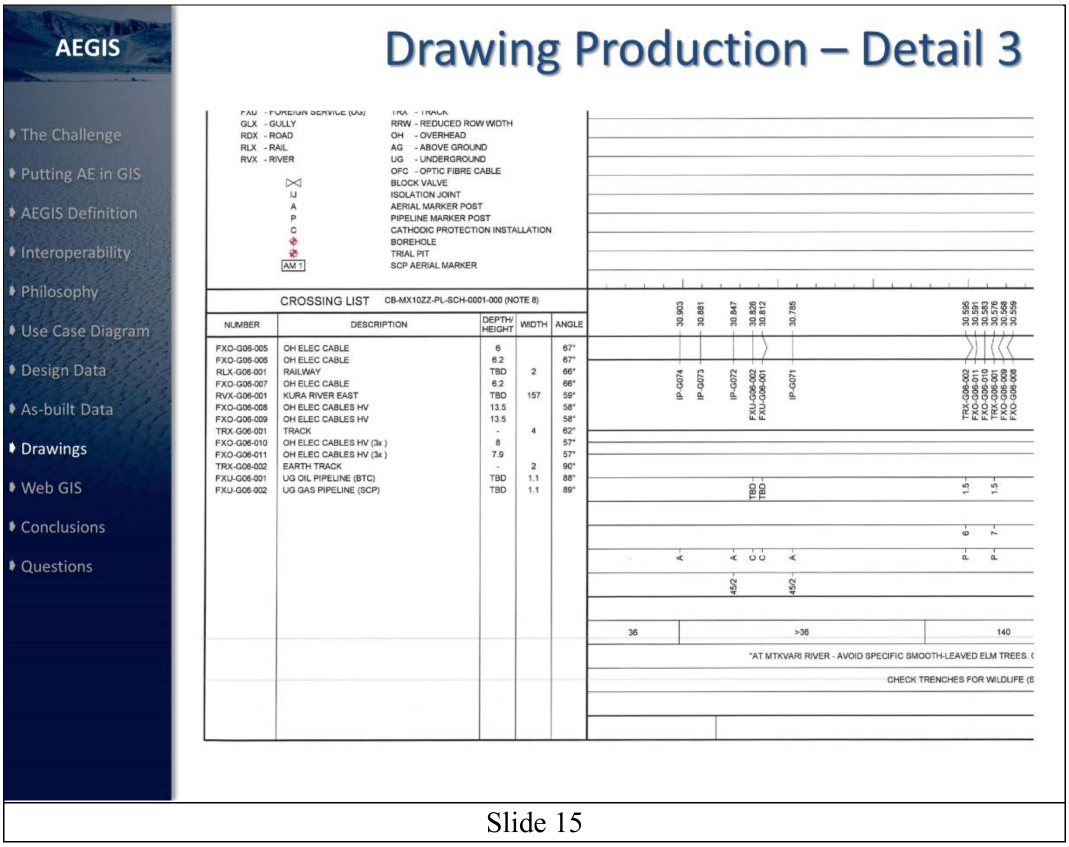
GENERAL NOTES

1. COORDINATE SYSTEM PARAMETERS:
   ELLIPSOID: KRASSOVSKY 1940
   PROJECTION: GAUSS-KRUGER
   GEODETIC DATUM: POLKOVO (1942) ZONE 8
   VERTICAL COORDINATE SYSTEM: KRONSTADT (BALTIC SEA) DATUM.
2. DRAWINGS ARE TO BE READ FROM RIGHT TO LEFT.
3. CHAINAGE IS 2D/PLAN IN KILOMETRES, ALL OTHER DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED. CONTOUR INTERVAL IS 1m.
4. WALL THICKNESS IS AS NOTED EXCEPT WHERE HEAVY WALL PIPE IS INDICATED, WHICH WILL BE ONE CLASS THICKER ie 16.7 WILL BECOME 20.1 AND 20.1 WILL BECOME 24.1.
5. STANDARD PIPELINE COVER IS 1m, UNLESS OTHERWISE STATED. FOR WATER COURSE CROSSINGS COVER IS TO BE MEASURED FROM THE TRUE CLEAN BOTTOM. WHERE GIVEN FOR FOREIGN SERVICE CROSSINGS THIS IS ESTIMATED BUT CONTRACTOR IS TO ENSURE MINIMUM SEPARATION.
6. WHERE ONE CHARACTER IS SHOWN, MARKER WILL BE PLACED ON THE NEGATIVE SIDE. WHERE TWO CHARACTERS ARE SHOWN THE SECOND MARKER IS ON THE POSTIVE SIDE.ALL MARKERS TO BE INSTALLED FACING AWAY FROM THE CROSSING. WHERE A CATHODIC PROTECTION INSTALLATION IS INDICATED REFER TO CP INSTALLATION SCHEDULE - GEORGIA No. CB-MX30ZZ-PL-SCH-0004-000.
7. STANDARD RIGHT OF WAY (ROW) WIDTH IS 36m UNLESS OTHERWISE STATED, LAND BOXES ARE SHOWN ON PLAN.
8. CONTRACTOR TO IDENTIFY AND VERIFY ALL CROSSINGS PRIOR TO CONSTRUCTION.
9. FOR C.O.W. AND BARRIER FENCING REQUIREMENTS BASED ON SEPARATION FROM OTHER HYDROCARBON PIPELINES REFER TO TYPICAL DRAWINGS.
10. ENGINEERING DATA SHOWN IN AREAS COVERED BY HCA DRAWING IS INDICATIVE ONLY AND THE HCA DRAWING TAKES PRECEDENCE.

DRAWING SPECIFIC NOTES

A LOCATION OF SHAFT

Slide 14



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Drawing Production – Detail 3

FXU - FOREIGN SERVICE (UG)
GLX - GULLY
RDX - ROAD
RLX - RAIL
RVX - RIVER

TRX - TRACK
RRW - REDUCED ROW WIDTH
OH - OVERHEAD
AG - ABOVE GROUND
UG - UNDERGROUND
OFC - OPTIC FIBRE CABLE

⋈	BLOCK VALVE
IJ	ISOLATION JOINT
A	AERIAL MARKER POST
P	PIPELINE MARKER POST
C	CATHODIC PROTECTION INSTALLATION
⊕	BOREHOLE
✱	TRIAL PIT
AM 1	SCP AERIAL MARKER

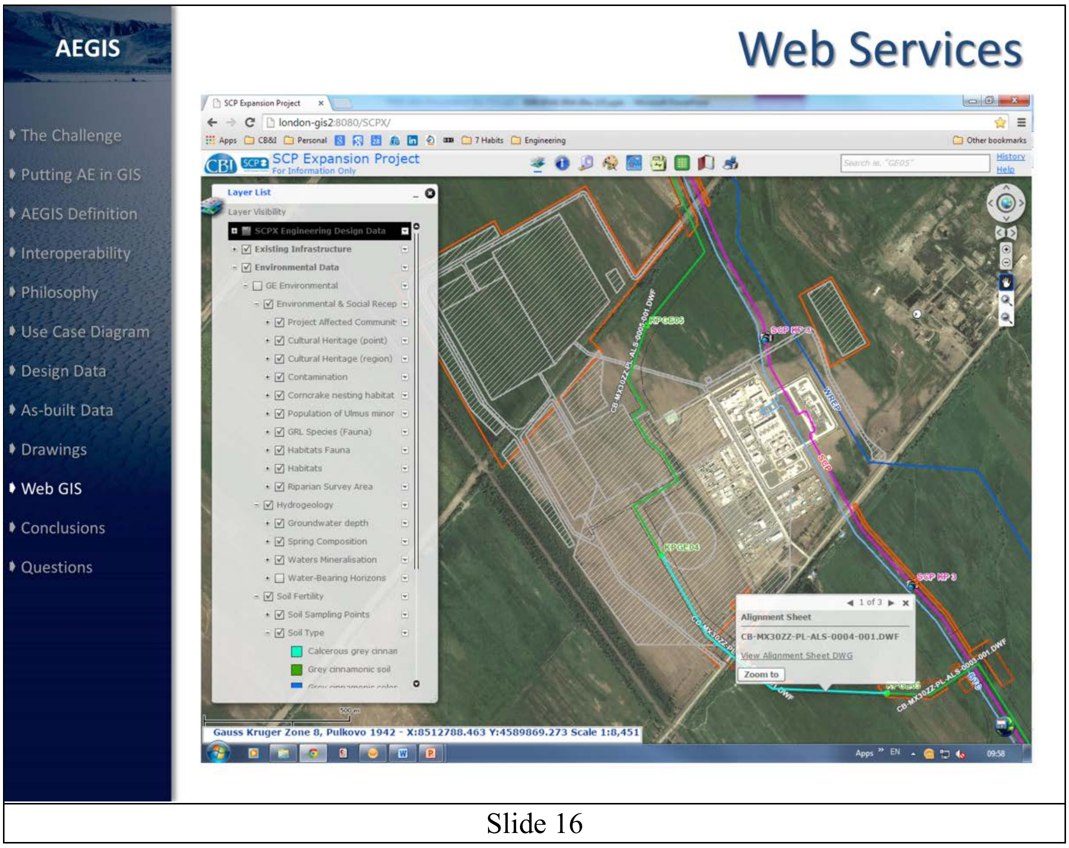
CROSSING LIST CB-MX10ZZ-PL-SCH-0001-000 (NOTE 8)

NUMBER	DESCRIPTION	DEPTH/ HEIGHT	WIDTH	ANGLE
FXO-G06-005	OH ELEC CABLE	6		67°
FXO-G06-006	OH ELEC CABLE	6.2		67°
RLX-G06-001	RAILWAY	TBD	2	66°
FXO-G06-007	OH ELEC CABLE	6.2		66°
RVX-G06-001	KURA RIVER EAST	TBD	157	59°
FXO-G06-008	OH ELEC CABLES HV	13.5		58°
FXO-G06-009	OH ELEC CABLES HV	13.5		58°
TRX-G06-001	TRACK	-	4	62°
FXO-G06-010	OH ELEC CABLES HV (3x)	8		57°
FXO-G06-011	OH ELEC CABLES HV (3x)	7.9		57°
TRX-G06-002	EARTH TRACK	-	2	90°
FXU-G06-001	UG OIL PIPELINE (BTC)	TBD	1.1	88°
FXU-G06-002	UG GAS PIPELINE (SCP)	TBD	1.1	89°

"AT MTKVARI RIVER - AVOID SPECIFIC SMOOTH-LEAVED ELM TREES. (

CHECK TRENCHES FOR WILDLIFE (S

Slide 15



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Web Services

1 of 3

Alignment Sheet

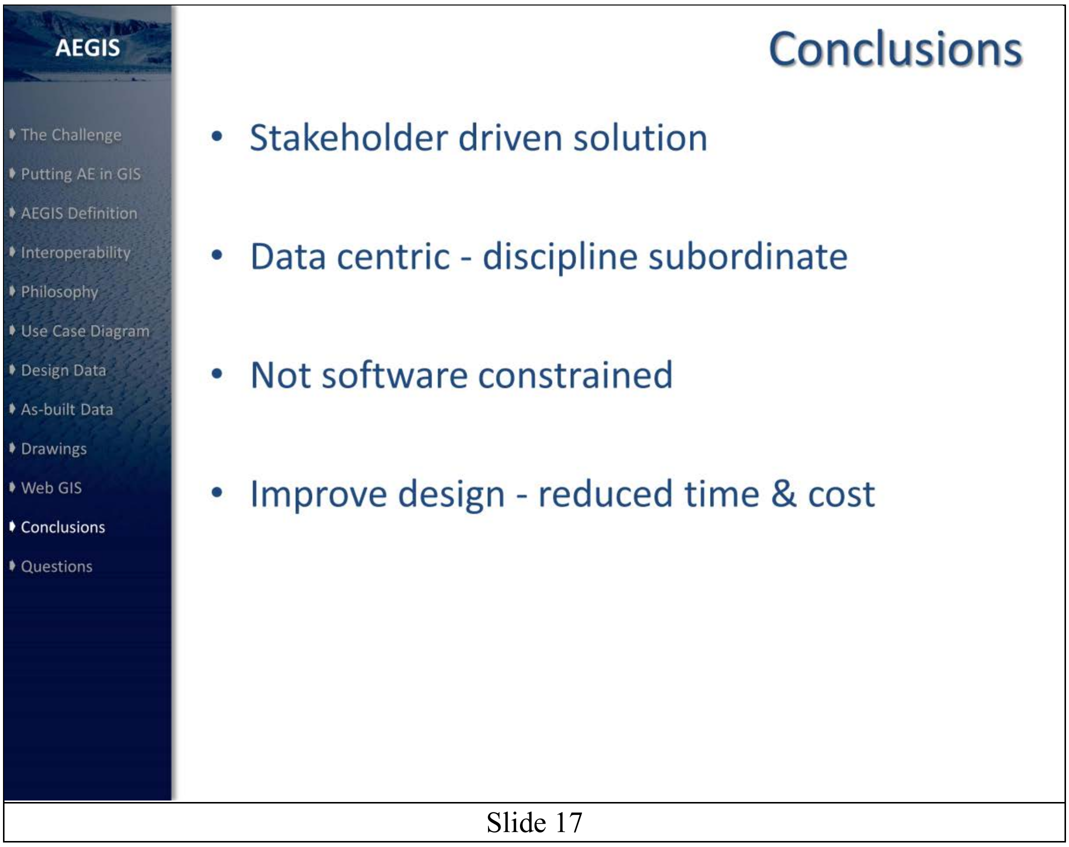
CB-MX30ZZ-PL-ALS-0004-001.DWF

View Alignment Sheet DWG

Zoom to

Gauss Kruger Zone 8, Pulkovo 1942 - X:8512788.463 Y:4589869.273 Scale 1:8,451

Slide 16



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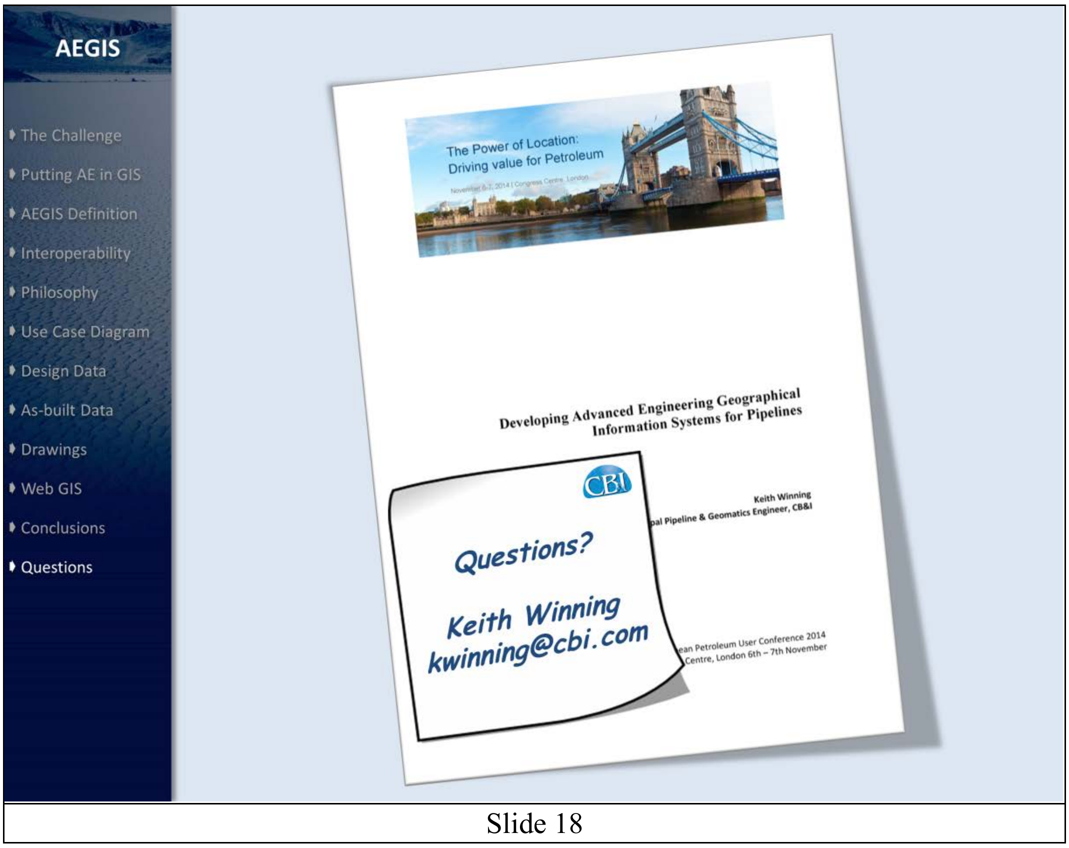
Conclusions

- Stakeholder driven solution
- Data centric - discipline subordinate
- Not software constrained
- Improve design - reduced time & cost

Slide 17



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pal Pipeline & Geomatics Engineer, CB&I

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CBI

Questions?

Keith Winning
kwinning@cbi.com

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