Groundwater Flooding – Unforeseen Consequences of Flood Control and Water Conservation in Dayton, Ohio

Brent E. Huntsman, CPG
Kelly C. Smith, CPG
Daniel J. Wagel
Terran Corporation
Groundwater Flooding

Typically undesirable water table rises above the land surface or into subsurface structures.
The Great Flood of 1913
Geologic Profile

LEGEND:

- Sand & Gravel Outwash
- Glacial Till or Clay-Dominated Soil
- Ordovician Shale/Limestone Bedrock

Groundwater Potentiometric Surface

Major Hydrogeologic Units

1. Upper Outwash Aquifer
2. Lower Outwash Aquifer
Pluvial Groundwater Flooding

• Groundwater rising – unconfined aquifer response to sustained rainfall
• Often preceded by above normal groundwater levels
• Long-lasting and regionally extensive
• Variables include aquifer properties, catchment size, location of recharge
• Example: Puget Sound, Washington
Fluvial Groundwater Flooding

• Lateral infiltration into unconsolidated sediments from flooded rivers
• Limited storage capacity
• Rapid response to rainfall and river levels
• Decline in river levels allows relatively rapid dewatering of sediments
• Circumvention of flooding protection
Post-Industrial Groundwater Flooding

• Decline in industrial activity leads to reduced abstraction and rising groundwater levels

• Groundwater enters buildings that were constructed when groundwater levels were lower

• Can be offset by increased pumping
Needs Statement

How can ground water levels in the downtown area of Dayton be accurately predicted to manage subsurface protection systems?
Modeling Approaches

• **Analytical Models**
  Example: Rorabaugh

• **Numerical Models**
  Example: MODFLOW

• **Artificial Neural Networks**
  Example: Your Brain
Computer Model Domain
Substructure Flooding
Potential Definitions

WATER TABLE @ NORMAL CONDITIONS

Great Miami River

10-YR.
50-YR.
100-YR.

10-Feet

10-Feet

10-Feet
Substructure Flooding Potential

ZONES OF POTENTIAL SUBSTRUCTURE FLOODING

- 10-Year Flood Recurrence Zone
- 50-Year Flood Recurrence Zone
- 100-Year Flood Recurrence Zone
ANN Models

A form of artificial intelligence that mimics information processing of the human brain and is used to discern functional relationships among selected data.

ANN models are trained, they learn and become experts for a specific problem.
Why Use ANN Models for Water Level Predictions?

- Can use large, complex data sets
- Generalized decisions from imprecise data
- Learn by example, iteratively trained and retrained
- Complete hydrogeologic characterization of a site is not necessary
Diagram of ANN Groundwater Model

Input Layer

Simple functions of measured values
1. Rainfall
2. River Stage
3. Temperature
4. Groundwater Elevation in MT-6 measured the previous day

Hidden Layer(s)

Neurons
- Connection weights
- Biases
- Activation functions

Output

Predicted elevations in MT-6
Measured elevations in MT-6 used to train the ANN model
Model Calibration & Predictions
ANN Model Results

MT-6 Model Using Rainfall, Temperature, River Discharge and Previous MT-6 Reading as Inputs

Date

Water Level (ft)
Temporary Remedial Actions

- Effective monitoring and warning systems required for timely response
- Withdraw water using existing protection wells
- Flooding substructures to counter buoyancy
- Valuables and hazardous materials to higher levels
- Shut off affected utilities
Long-Term Remedial Actions

• Depends on risk assessment, mapping, and history of groundwater levels
• Enact requirements for appropriate construction: no or limited substructures; specialized construction
• Move building utilities above flood level
• Install protection wells and backup power
• No hazardous materials stored in affected areas
Epilogue