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GROUND WATER RESOURCES

Terranext personnel have extensive experience in ground water resource development, including the following services:

- *Pumping well design*
- *Development of well specifications*
- *Well construction supervision/quality control*
- *Well field design/management*
- *Design of river bank filtration systems*
- *Aquifer safe yield analysis*
- *New water supply exploration*
- *Ground water/surface water interaction*
- *Construction dewatering*
- *Aquifer testing and characterization*
- *Numerical/analytical modeling*
- *Geophysical surveys*
 - *Surface*
 - *Borehole*

Primary Ground Water Professionals:

Luca DeAngelis, P.E., R.G., Geological Engineer/Hydrogeologist

Mr. DeAngelis is a registered professional engineer and registered professional geologist with 10 years of experience in the environmental and water supply industries specializing in geological engineering, hydrogeology, and numerical modeling.

Christopher Kinn, R.G., Senior Geophysicist

Mr. Kinn is a registered professional geologist with over 14 years of experience in the environmental, water supply, and mining industries specializing in exploration geophysics and hydrogeology.



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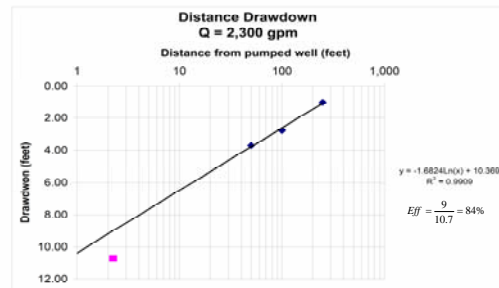
WATER SUPPLY WELL DESIGN

Terranext has experience in the design and performance testing of water supply wells. Typical well design services provided include:

- **Development of construction specifications**
 - Vertical wells
 - Angle wells
- **Determination of appropriate drilling method**
- **Filter pack and screen slot size selection**
- **Supervision of well installation contractor**
- **Well performance testing – instrumentation and analysis**
 - Step tests
 - Constant rate tests
- **Determination of sustainable well yield**

Construction supervision includes:

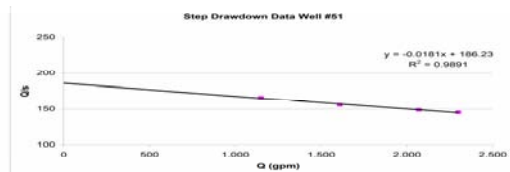
- **Supervision of drilling contractor – ensure compliance with drilling specifications**
- **Development of a boring log and well completion diagram**
- **Well performance testing – estimating well efficiency**



- **Step rate test analysis – single well test well efficiency analysis**

Well Efficiency Based on Stepped Rate Pumping Test
Bierschenk Method (1964)

Step	Q (gpm)	Static Water Level (ft below TDC)	Pumping Water Level (ft below TDC)	Observed Drawdown (feet)	Specific Capacity (gpm/ft)	Y intercept (maximum theoretical specific capacity)	% Efficiency
1	1,350	8.1	13.9	8.9	186	186	80%
2	1,630	8.2	18.2	10.3	158	186	84%
3	2,070	8.3	20.0	13.9	149	186	80%
4	2,300	8.4	21.8	15.6	145	186	78%



NEW WATER SUPPLY EXPLORATION

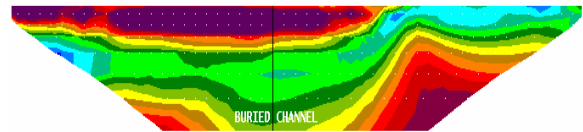
Terranext personnel have experience in the siting of water supply wells and can utilize a variety of geophysical surveys to aid in the location of water supply wells in complex hydrogeologic terrain.

Performing geophysical surveys can minimize the potential of drilling a dry hole and aid in intelligent land purchases.

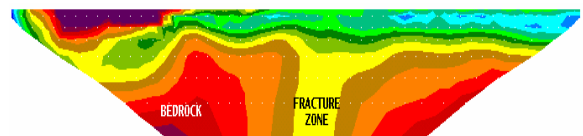


Hydrogeologic exploration includes:

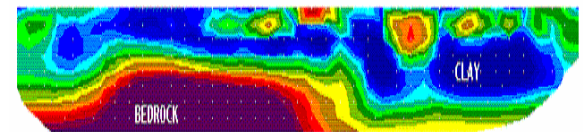
- **Glacial channel mapping**



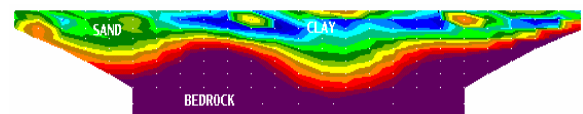
- **Bedrock fracture mapping**



- **Bedrock topography mapping**



- **Sand and gravel mapping**



AQUIFER TESTING AND CHARACTERIZATION

Terranext scientists and engineers are experienced in design and instrumentation of aquifer tests to determine aquifers parameters. Specific expertise includes:

- *Aquifer test design*
- *Aquifer test instrumentation/data collection*
- *Slug testing - rising head/falling head tests*
- *Calculation of aquifer characteristics*
- *Evaluation of ground water quality*



Typical aquifer characteristics determined:

- *Hydraulic conductivity*
- *Storage coefficient*
- *Transmissivity*
- *Permeability*
- *Radius of influence*
- *Well efficiency*
- *Impervious groundwater boundaries that limit the aquifer*
- *Existence of unknown recharge sources*





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WATER SUPPLY PLANNING/ WELL FIELD DESIGN AND MANAGEMENT

Terranext works with county and city governments, as well as private utilities, to develop comprehensive water supply plans which incorporate regulatory requirements with the water supply needs of the area. Terranext has extensive experience in planning and permitting and can utilize many of the following techniques to achieve both continued economic expansion and protection of vital water resources.



Services provided include:

- *Well field design*
- *Well field management*
- *River bank filtration system design*
- *Surface and groundwater water permitting*
- *Aquifer safe yield studies*
- *Wellhead/source water protection studies*
- *Well field source water analysis*
- *Public awareness and education*
- *Water demand studies*
- *Evaluation of alternative aquifers and surface water resources*
- *Conservation planning*
- *Re-injection of treated water*
- *Alternative uses for wastewater*
- *Groundwater quality sampling and reporting*
- *Surface water and storm water sampling and reporting*



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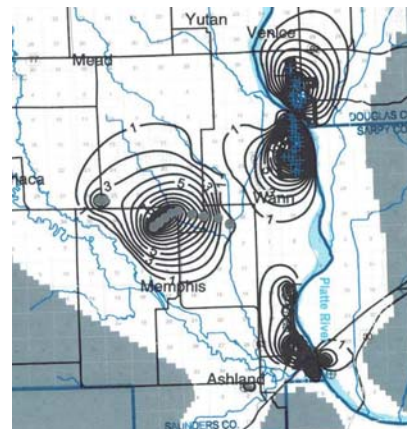
NUMERICAL/ANALYTICAL MODELING

Terranext hydrologists have extensive experience in numerical and analytical ground water modeling. Terranext hydrologists develop ground water models to support major ground water projects. Care is taken to develop a model that accurately reflects the project conceptual model. Depending on the project needs, Terranext can develop a simple analytical model or a complex numerical model. Typical model codes used include the following:

- **Ground Water Flow**
 - **MODFLOW 2000**
 - **MODFLOW-SURFACT**
 - **SWIFT**
 - **WHPA**
- **Particle Tracking**
 - **MODPATH**
 - **PATH3D**
- **Solute Transport**
 - **MT3DMS**
 - **RT3D**
- **Monte Carlo analysis**
- **Parameter estimation modeling**
 - **PEST**
 - **MODAC**

Typical modeling applications include:

- **Well field design**
- **Well field management**
- **Aquifer safe yield studies**
- **Wellhead/source water protection studies**
- **Contaminant transport analysis**
- **Hydraulic containment system design**
- **Optimization studies**
- **Regional basin planning**
- **Conjunctive use studies**
- **Ground water/surface water interaction studies**



GEOPHYSICAL SERVICES

Geophysical surveys provide a cost effective, non-intrusive way to gain information on the subsurface.

Geophysical surveys can be performed quickly and efficiently. An understanding of the subsurface over the entire survey area can be used to intelligently pick areas for further exploration or monitoring.

When low impact exploration is required, geophysics should be considered. Geophysical surveys are non-intrusive and allow minimum impact to the survey area.

Terranext offers a broad range of geophysical services that can aid in the intelligent placement of test holes, monitoring wells, and water supply wells.

Geophysical methods that Terranext utilizes include:

- *DC Resistivity*
- *Seismic Refraction*
- *Electromagnetic (EM)*
- *Time Domain EM (TEM)*
- *Magnetics*
- *Magnetotellurics (MT)*
- *Ground Penetrating Radar (GPR)*
- *Borehole Geophysics*



Geophysical applications include:

- *Archeological Mapping*
- *Saltwater Intrusion Mapping*
- *UST Investigations*
- *Contaminant Plume Mapping*
- *Abandon Landfill Mapping*
- *Leachate Mapping*
- *Abandon Mine Mapping*
- *Water Supply Well Locating*
- *Bedrock Mapping*
- *Aquifer Characterization*
- *Karst Feature Mapping*
- *Water Table Mapping*
- *Bedrock Fracture Mapping*
- *Buried Channel Mapping*



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**SELECTED WATER
RESOURCES
CLIENTS**

- *HDR Engineering, Inc.*
- *Bartlett and West Engineers*
- *Kleinfelder*
- *Central Iowa Water Association*
- *Lewis and Clark Rural Water System (Sioux Falls, South Dakota)*
- *Metropolitan Utilities District (Omaha, Nebraska)*
- *Lincoln Water Systems (Lincoln Nebraska)*
- *City of Spearfish, South Dakota*
- *City of York, Nebraska*
- *Kansas Department of Health & Environment*
- *Madison Mining Company*



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PROJECT DESCRIPTION

WELL FIELD DESIGN/MANAGEMENT

**Metropolitan Utilities District
Omaha, Nebraska**

- **Designed 52 mgd well field for the City of Omaha, NE**
- **Designed and performance tested 42 production wells**
- **Provided field support during construction of 42 new supply wells**
- **Developed a ground water model to evaluate impact of the new well field on aquifer and stream flow in Platte River**
- **Ground water model reviewed and approved by USACE, HTRWCX, USEPA, CSMOS (USEPA Ada)**
- **Designed instrumentation system to monitor the impact of the well field**
- **Compliance reporting for 404-Permit**
- **Held public meetings**

PROJECT DESCRIPTION

WATER SUPPLY PLANNING

**Heart of Georgia Regional
Development Center
Baxley, Georgia**

- **Response to saltwater intrusion in the Floridian Aquifer**
- **Southeast Georgia counties required to develop Water Supply Plans**
- **Terranext developed plans for four counties – Appling, Tattnall, Toombs, and Wayne**
- **Collected data on current water demand, water supply, and wastewater treatment**
- **Based on usage trends projected future demands**
- **Presented alternative surface water and shallow aquifer sources as well as conservation techniques**
- **Held public meetings**



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PROJECT DESCRIPTION

WELL FIELD PLANNING/DESIGN

***Lewis and Clark Rural Water System
Sioux Falls, South Dakota***

- ***Planning/designing a 50 mgd well field for the City of Sioux Falls, SD and several Rural Water Systems***
- ***Assisted A/E design firm in developing the well field 30 percent pre-design document***
- ***Designed five angle and two vertical water supply wells***
- ***Developed plans and specifications for full scale angle and vertical wells***
- ***Developed a ground water model to estimate the safe yield of the aquifer and impact of well field operation on stream flow in Missouri River***
- ***Analysis of a 72-hour pumping test***

PROJECT DESCRIPTION

WELL DESIGN/AQUIFER TESTING

***Lincoln Water Systems
Lincoln, Nebraska***

- ***Developed plans and specifications for replacement of two vertical wells***
- ***Reviewed well drilling contractor aquifer test data and report***
- ***Analysis of a 48-hour pumping test***
- ***Determined well efficiencies for new supply wells to ensure compliance with well specification***
- ***Estimated sustainable long term well yield***



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PROJECT DESCRIPTION

NEW WATER SUPPLY PLANNING/NUMERICAL MODELING

**City of York
York, Nebraska**

- ***Planning/designing an expanded well field***
- ***Existing wells impacted by Arsenic, Nitrates, and Uranium***
- ***Drilled test borings and installed new observation wells***
- ***Determined most favorable location for a new well field, based on water chemistry and projected well yield***
- ***Developed detailed six layer numerical model to evaluate well field source water***

PROJECT DESCRIPTION

GROUND WATER/SURFACE WATER INTERACTION – NUMERICAL MODELING

**Metropolitan Utilities District
Omaha, Nebraska**

- ***Reviewed historical stream flow data for Platte River and minor creeks***
- ***Developed surface water flow duration curves and rating curves for available USGS gauging stations***
- ***Developed exceedance intervals for streams***
- ***Estimated base flow for creeks and Platter River using Base Flow Index technique***
- ***Estimate Base Flow using 7Q10 technique***
- ***Evaluated surface water/ground water relationship for various flow conditions***
- ***Used flux targets to improve calibration of numerical model***



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PROJECT DESCRIPTION

HIGH CAPACITY WATER WELL EXPLORATION

**Central Iowa Water Association
Waverly, Iowa
Sigourney, Iowa**

- **Fractured bedrock characterization for water supply wells**
- **Fracture trace study to determine potential fracture locations**
- **Geophysical survey to determine exact locations of fractures in bedrock**
- **Test drilling revealed fractures and open cavern at depth and subsequent high yield water well installed (~2,000 gpm)**

PROJECT DESCRIPTION

SITE ASSESSMENT – Subsurface Characterization

**Kleinfelder
Kansas City, Missouri
Overland Park, Kansas**

- **Prepared optimal geophysical survey design for subsurface electrical characterization**
- **Conducted geophysical survey to locate underground storage tanks and associated piping**
- **Presented geophysical results including tank and piping locations to aid in subsurface drilling activities**



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PROJECT DESCRIPTION

DRINKING WATER PROTECTION

**Kansas Department of Health & Environment
Topeka, Kansas**

- **Contractor for State of Kansas Water Plan for 9 years**
- **Hundreds of sites requiring ground water cleanup**
- **Dozens of sites requiring alternative and emergency drinking water supply**
- **Waterline design and construction oversight**
- **Wellhead treatment systems**
- **Innovative remediation technologies**
- **Site investigations & aquifer studies**
- **Designed, constructed, and installed nearly 100 air sparge and SVE systems**

PROJECT DESCRIPTION

- **Water Line Extension and Connection, Colby, Kansas**
Design and install municipal water line extension for connection of private and industrial water supply wells impacted by hexavalent chromium
- **Alternative Water Supply for Impacted Residences, Various Sites throughout Kansas**
Implement a plan to provide temporary water supply to residences where private wells have become impacted
- **Water Supply Wellhead Treatment Systems, Various Sites throughout Kansas**
Design and install wellhead treatment system for impacted public water supply wells

