USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Geomorphology and Sedimentology of the Canadian River Alluvium Adjacent to the Norman Landfill, Norman, Oklahoma

Focus Categories: G&G, SED

Keywords: Geomorphology, Sedimentology, Permeability, Landfill

Duration (month/year to month/year): March 1, 2000 to February 28, 2001

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Principal Investigators' Names and University:

Dr. Richard A. Marston and Dr. Stanley T. Paxton
School of Geology
105 Noble Research Center
Oklahoma State University
Stillwater, OK 74078-3031

Congressional District of University where the Research is to be Conducted: 3rd U.S. Congressional District

Statement of Critical Regional or State Water Problems

The Norman Landfill is a closed municipal landfill located on the floodplain of the Canadian River in Norman, Oklahoma (http://wwwok.cr.usgs.gov/public/proj/proj_ok104.html). The landfill accepted solid waste from the city between 1922 and 1985, at which time the landfill was closed with a vegetated clay cap. On-going research conducted by the Oklahoma District Office of the U.S. Geological Survey is identifying the extent of a single leachate plume from the landfill. However, the geomorphic and sedimentologic characteristics of the floodplain and active channel have yet to be documented. These characteristics will control the permeability of the floodplain, and therefore, the migration potential of leachate plumes, known and unknown (personal communication, Scott Christenson, 12/03/99).

Statement of Results or Benefits

The results of this project will be presented to the Oklahoma District Office of the U.S. Geological Survey as a written report describing the problem statement, study area, objectives, methods, results, and conclusions. Appendices containing raw data will be included. The report will be illustrated with appropriate figures and tables. Major topics to be addressed in the report are: a) the geomorphic stability of the Canadian River upstream, adjacent, and downstream of the Norman Landfill in a manner that can be used to assess past and future mobility of contaminants in particulate form; and b) the vertical and horizontal heterogeneity in texture of floodplain alluvium to facilitate understanding of permeability pathways. If it is important to USGS to have more accurate (closer to absolute) estimates of permeability, experiments should be performed that measure porosity and permeability directly from the core materials. The proposed work would include both conventional (non-overburden corrected) and special (overburden corrected) core analyses. It is generally recognized that very significant compaction (porosity / permeability decrease) occurs in sands and muds in the upper 1000m of burial. The compaction trajectory in the upper few hundred meters of burial is not well documented, but could be very significant.

Nature, Scope, and Objectives of the Research

Inspection of historical aerial photographs reveals that the Canadian River has experienced significant horizontal migration over the past few decades in the region of the Norman landfill, initiating episodes of erosion and deposition. Lateral channel instability is expected for a sand-bed, meandering river, but bank protection has truncated meander migration. Further complicating the situation, upstream reservoirs have changed the water-sediment budget that might be expected to trigger vertical channel instability in the vicinity of the landfill. Understanding channel stability would enable more informed judgements about the likelihood that stream erosion could mobilize contaminants from the landfill in particulate form. We might anticipate a correspondence between spatial and temporal patterns of channel stability and the vertical and horizontal connectivity of alluvial units.

This study emphasizes 1) collection and analysis of aquifer sediment textural data and 2) establishing associations between aquifer properties and the Canadian River Valley geomorphology. Once the data are collected, analyzed, and the strength of association between the aquifer properties and the geomorphology demonstrated, attention can then turn to the best methods for USGS to computer model the aquifer flow behavior around the Norman Landfill. Our focus on aquifer properties stems from our experience with permeability distribution in both aquifers and petroleum reservoirs.

The specific objectives of our proposed research are to describe and explain:

1) the geomorphic stability of the Canadian River upstream, adjacent, and downstream of the Norman Landfill in a manner that can be used to assess past and future mobility of contaminants in particulate form; and

2) the vertical and horizontal heterogeneity in texture of floodplain alluvium to facilitate understanding of permeability pathways.

Achieving the first objectives will facilitate assessment of past and future mobility of contaminants in particulate form. Achieving the second objective will lead to understanding of sampling strategies appropriate for understanding heterogeneity of floodplain alluvium and the influence of this on permeability and movement of leachate plumes.

Methods, Procedures and Facilities

The first objective will be achieved by using historical aerial photos to produce geomorphic maps of the Canadian River describing a reach extending approximately 2 km upstream and 2 km downstream of the Norman Landfill (Figure 1). Exact study length will be discussed with USGS Norman Landfill project personnel. The maps would delineate current topographic units, including the active channel (past and present), as well as floodplain and in-channel microtopography (e.g., meander scrolls, chutes, point bars) (see attached figures). Meander migration over the past 50 years will be described and explained in terms of watershed factors, climate trends, and human interference.

The second objective will be achieved in two stages. First, a preliminary sampling (grid pattern) of cores near the known plume will be undertaken to define the degree of textural heterogeneity to be expected elsewhere. Second, the floodplain and active channel adjacent to the landfill will be sampled following criteria established in stage one. Cores to a depth of approximately 12 meters will be acquired using a Geoprobe provided by the USGS Oklahoma District Office. The stratigraphy will be logged and textural analyses conducted for each stratigraphic unit in each core. These data will be assembled to describe depositional environments associated with past channel position.

<u>Core Photographs</u>: Cores for each well will be photographed at a range of scales in order to document the bedding, sedimentary structures, and sediment textures. Color balance charts and scales will be included in all photographs. We plan to use a digital camera for some of this work. For non-digital photography, we have the capability to transform all print negatives and slides into digital image files.

<u>Core Description</u>: Recovered core materials will be described and the information logged on standardized strip-log sheets (example sheet attached) in the laboratory. We will attempt to use a scale of 1 cm of strip log = 10 cm of recovered core (or about 1 inch = 1 foot), though the exact scale will vary with the quality of the Geoprobe core recovered (extent of core disturbance) and with the amount of observed lithologic variation.

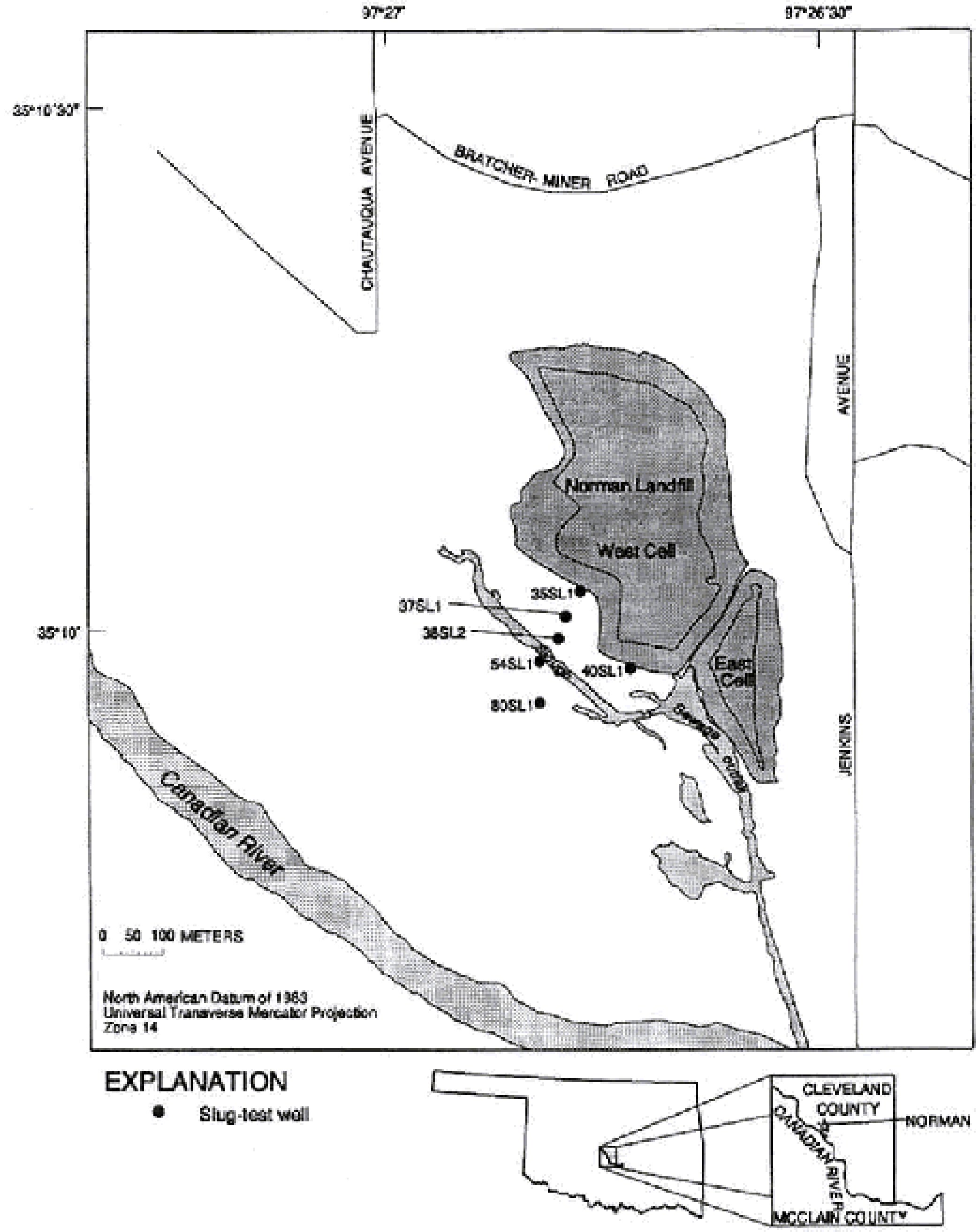

Figure 1. The Norman Landfill and surrounding area. The landfill mound is about 8 to 11 meters above the surrounding land surface and is divided into two cells separated by the sewage treatment plant discharge pipeline.

(from Scholl and Christenson, 1998)

Descriptions will include lamina / lamina set and bed / bed set thicknesses, lithology, and sedimentary structures. Color (Munsell Soil or GSA Rock Color Charts), texture (grain size / sorting), shape, and roundness of the sediment will be determined from visual comparitors using a binocular laboratory microscope. Estimates of mineral abundances will be recorded in the laboratory. However, it is recommended that a few samples be evaluated with thin-section petrography and x-ray diffraction (XRD) across a range of grain sizes. It is important to evaluate the mineralogy across a range of grain sizes because detrital mineralogy in sediments commonly varies with grain size. Consequently, the mineralogy in coarse-grained intervals will be different than the mineralogy in the fine-grained intervals. These differences in mineralogy can translate to differences in sediment permeability due to differences in grain shape and ductility. Obvious vertical associations that can be attributed to depositional environment and / or geomorphic units will be noted.

The strip logs will be digitized and imported to RockWare's LogPlot98 software package for display. This software can also accommodate digital photographs. The LogPlot98 files can be imported to XXXX software for the generation of stratigraphic cross sections.

Core Gamma-Ray Profiles: We propose to measure the gamma rays emitted from the core material through the use of a hand-held gamma ray scintillometer. Assuming that the background radiation is not too high, we will then construct vertical profiles that can be used to quantitatively relate the gamma ray profiles to the sieve analysis summary statistics.

It is commonly recognized that potassium-bearing minerals in sediments emit gamma rays that reflect sediment grain size. This is because potassium tends to be enriched in finer-grained materials such as clays and micas. In addition, we know that permeability in the granular material varies with grain size. Consequently, construction of gamma-ray profiles will help us to identify and estimate vertical permeability variations.

The pattern of the profiles (e.g., coarsening upward, fining upward, or blocky) can be used to fingerprint the depositional environments and associations with the mapped geomorphic units. Moreover, we will attempt to establish an association between the profiles, depositional facies, and stratigraphy. If this portion of the work is successful, gamma-ray logging of wells in future landfill sites could be used as a way to define the permeability structure and reduce analytical costs.

Grain-Size Sieve Analysis: From a practical point of view, the most important controls on the permeability structure in these deposits will be 1) the sediment lithology (sand and gravel vs. silt and clay) and 2) the size and sorting of the sand and gravel intervals. The sediment lithology is important because the silt and clay intervals will define the permeability barriers in the aquifer. The sediment grain size and sorting are important because they determine the size of the pore-throats within the permeable intervals.

After the core material has been dried and locally disaggregated, a 25g sample will be prepared for sieve analysis from each one-meter increment of the core. In cases where more than 25g of material are available within the vicinity of the one-meter increment, the sample will be split with a mechanical sample splitter. Where bedding styles, lithology, and grain size change perceptibly at intervals less than one meter, we will select sub-one meter increments for sieve analysis if enough sediment is present. Each sample will be sieved for 20 minutes.

Currently, we do not plan to do settling tube or pipette size analysis of the clay-sized materials. This is because, relative to the sands and gravel intervals, the clay layers are already recognized to be permeability barriers (Scholl and Christenson 1997). We expect most of the variation in permeability to occur between and within beds of sand and gravel. For this reason, more of our effort will focus on the texture of the silt, sand, and gravel fractions. We will be able to generate sieve size fractions down to about 25 microns (medium silt).

The sieve data on the screens will be weighed and the data tabulated (about nine size fractions at a minimum). We will then generate histograms and cumulative frequency distributions for each of the samples. Summary statistics (mean, median, mode, standard deviation, skewness, kurotosis, and sorting) will be generated using the graphical techniques outlined in Folk (1980).

During our data analysis phase we will perform simple statistics tests (e.g., t-tests) in order to demonstrate whether or not observed differences in population means for / between 1) depositional environments, 2) geomorphic units, and 3) stratigraphy are real and significant.

<u>Estimating Permeability from Sieve Data</u>: Since we are not measuring permeability directly from the cored material, values must be calculated from our textural and lithologic data. There are numerous techniques and algorithms available for calculating permeability of sediment. However, most of these techniques require values obtained from measurement of porosity and other variables that are unavailable to us. We intend to generate an empirical equation using the raw data generated by the laboratory experiments of Beard and Weyl (1973). Their work, entitled, ‘Influence of texture on porosity and permeability of unconsolidated sand’, contains results in table form that can be used to generate a multivariate predictive equation for permeability from grain size, sorting, and porosity. Past evaluation of the data set (by co-PI Paxton) provided in the Beard and Weyl paper indicates that the raw data are internally consistent. Though our permeability estimates may not be correct in the absolute sense, our estimates and the relative differences between samples will be consistent throughout the study.

As with the sieve data, statistical tests will be performed (e.g., t-tests) in order to demonstrate whether or not observed differences in permeability population means for / between 1) depositional environments, 2) geomorphic units, and 3) stratigraphy are real and significant. However, as the permeability values will be derived from the textural data, significant differences in texture relative to the geomorphology will by definition result in significant permeability differences.

<u>Thin Section Petrology</u>: Thin section analysis (point-count mineralogy and grain size measurement) will be performed on 10 to 20 samples from each of the wells. The purpose of this analysis will be to document mineral types, sizes, and sorting as grouped by

depositional facies and / or geomorphic units. Thin section photomicrographs will help to visually communicate why permeability of sediment varies strongly with grain size and sorting. Petrography procedures and grain classification scheme will follow those outlined in an unclassified Exxon document (Cochran et al. 1986).

X-Ray Diffraction (XRD): Ten samples of aquifer sediment will be analyzed by XRD. Samples will correspond to the thin section samples locations in the core. Our intent is to identify mineral phases and not relative abundances of the phases.

The project can be completed in the funding period from 1 March 2000 to 28 February 2001. Coring schedules will be coordinated with the USGS Oklahoma District Office. Core description, textural analyses, and analyses of aerial photos can be conducted in labs within the OSU School of Geology.

Related Research

The lateral and vertical geomorphic instability of wide-shallow sand-bed rivers has been the subject of numerous studies, perhaps best encapsulated in the work by Schumm (1977) for the Great Plains of the U.S. and by Petts et al. (1989) for large European Rivers. Studies by Graf (1984) and Marston (1995) have demonstrated the usefulness of geographic information systems in analyzing channel instability and floodplain disturbance. The relation between stream channel instability and sedimentology of alluvium has been the subject of studies for many years (e.g., Selley 1976, Collinson 1978), recently enhanced by the computer models with three-dimensional visualization.

The proposed project will contribute to the on-going Norman Landfill Toxic Substances Hydrology Program under the direction of the Oklahoma District Office of the U.S. Geological Survey. This program was initiated in 1994 with four research objectives: 1) Characterize the ground-water flow system and the ground-water/surface-water interaction; 2) characterize the chemical and mineralogical substrates and describe the variation in lithology and the distribution of permeability; 3) characterize the composition and temporal/spatial variability of inorganic and organic constituents in the leachate plume; and 4) determine biogeochemical processes that affect contaminant distributions. Our proposed study addresses objective #2 above. One particular publication from the Normal Landfill program is of direct relevance to the proposed work, published as USGS Water-Resource Investigations Report 97-4292 (Scholl and Christenson 1998). Scholl and Christenson used slug tests to characterize hydraulic conductivity along a 215-meter transect on the floodplain alluvium adjacent to the Norman Landfill. This study identified strong sedimentological controls on movement of the contaminant plume from the Norman Landfill. Hydraulic conductivities varied over four orders of magnitude. The study demonstrated a need for additional information beyond the single transect on permeability structure of the alluvium.

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