ENV. GEOL. 6-A

1975

EXPLANATION

Pleistocene and Holocene

Qvf

Valley-fill deposits

Generalized, undifferentiated valley-fill deposits composed primarily of alluvial gravel, sand, and silt; highly variable composition and thickness (10 to 80 ft); significant shallow aquifer throughout much of the area.

Upper Cretaceous

Kl

Laramie Formation

Light- to dark-gray interbedded silty sandstone, siltstone and carbonaceous shale; limonite staining and other oxidation products common; approximately 200 ft of lower Laramie present within study area; bedrock outcrops uncommon.

Kfm

Fox HillS Sandstone

Tan to yellow sandstone; fine-grained, well sorted; thick-bedded to massive subparallel bedding with some low-angle cross-stratification; many calcareous and ferruginous concretions scattered through the entire section; approximately 60 ft thick. This unit has been locally mapped as the Milliken Member of the Fox Hills.

Kptz

Pierre Shale Transition Zone

Medium- to dark-gray shale, siltstone, and sandstone; thinly interbedded and grading upward from shale to dominantly siltstone and silty sandstone; section is 2000 to 3000 ft thick and includes what has been mapped by others as Lower Fox Hills. Stippled areas show prominent sandstone zones.

Kp

Pierre Shale

Dark-gray shale; lower part contains bentonite (montmorillonite clay); middle part contains prominent ridge-forming sandstones; section thickness 5000 to 8000 ft. Stippled areas show prominent sandstone members.

Kn

Niobrara Formation

Dark-gray calcareous shale; fossiliferous; thin bentonite and sandstone layers; lowest part of section is gray, thick-bedded limestone of the Fort Hays Member; only a small portion of formation above the Fort Hays is present in mapped areas.

Contact

Dashed where approximately located; dotted where concealed.

Strike and dip of beds.

REFERENCES

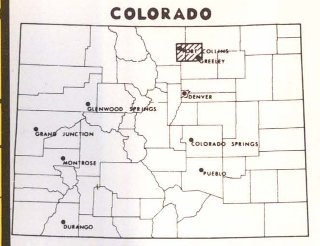
Briscoe, H. J., Jr., 1972, Stratigraphy and aquifer characteristics of the Fox Hills sandstone in the Greeley area, Weld County, Colorado: Colorado School Mines, Master Sci. Thesis T-1456, 78 p., 7 pls.

Colton, R. B., 1974, Personal commun.

Hershey, L. A., and Schneider, P. A., Jr., 1964, Ground-water investigations in the lower Cache la Poudre River basin, Colorado: U. S. Geol. Survey Water-Supply Paper 1669-X, 22 p.

________ 1972, Geologic map of the lower Cache la Poudre River basin, north-central Colorado: U. S. Geol. Survey Misc. Geol. Inv. Map I-687.

Mather, F. K., Gilluly, James, and Lusk, R. G., 1928, Geology and oil and gas prospects of northeastern Colorado: U. S. Geol. Survey Bull. 796-B, 124 p.



INDEX MAP

ADAPTED FROM BASE BY U.S GEOLOGICAL SURVEY, FRONT RANGE URBAN CORRIDOR PROJECT

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.

BEDROCK GEOLOGY

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, COLORADO GEOLOGICAL SURVEY

SCALE 1:48,000

1/2 0 1 2 3 4 5 MILES

1/2 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS

TRUE NORTH
MAGNETIC NORTH
13° 22.5'

APPROXIMATE MEAN DECLINATION, 1973

ENVIRONMENTAL GEOLOGY 6-B

1980

EXPLANATION

Sand and gravel underlying modern floodplain and older alluvial deposits (GP, GW, SP, SM); commonly stratified with lenses of finer material; clasts are well-rounded; gravels generally consist of granitic and metamorphic crystalline rocks derived from the Front Range; predominant grain sizes generally decrease from boulders near the mountain front to cobble and pebble sizes in the east; deposits generally have high bearing strength (except areas of high silt or silty sand content); however, shallow groundwater and flooding potential may exclude many areas from development; ease of excavation varies according to coarseness of deposit and degree of cementation; generally less than 50 ft thick; minor drainages not shown on this map normally have a high organic content but otherwise reflect the local soil type.

- Modern floodplain alluvial deposits.
- Older terrace deposits containing highly weathered clasts with thick caliche coatings.
- Finer gravels (< 1/2 in. diameter) in secondary or ancient drainages.

Eolian silt and fine sand (loess) deposited downwind from floodplains and weathered bedrock (SM, ML); soil profile in older deposits is characterized by filaments or nodules of caliche; soils generally have low to moderate swelling potential and may be prone to settling when saturated and loaded; generally less than 15 ft thick, however, dunes may be as thick as 50 ft; greatest thickness occurs in dunes, topographic depressions and on lee slopes of hills.

- Sandy loess
- Silty or clayey loess

A mixture of sand and red clay of alluvial fan/pediment deposits (GP, SP, SC, CL); clasts are angular; deposits are poorly sorted and poorly stratified; clasts are deeply weathered; caliche development is strong; surface topography reflects subtle fan morphology and may have thin cover of eolian sand and silt; clayey soils have moderate to high swelling potential; up to 15 ft thick.

- Alluvial fan/pediment deposits.

Weathered sandstone, siltstone, and shale with admixtures of eolian sand and silt (ML, CL, SM, SC); includes residual soil, colluvium, and bedrock outcrops; surficial soil textures generally reflect underlying shallow bedrock as depicted on plate 6-A; older deposits have strong caliche development; both soils and bedrock generally have moderate to high swelling potential; silty and sandy soils may settle when saturated and loaded; depth to bedrock normally less than 8 ft.

- Sandy soils
- Silty soils
- Clayey soils

DISCUSSION

This map is designed to provide a generalized textural classification of surficial and shallow soils in the Windsor Study Area. It is based primarily on an interpretation of surficial geology and inferences based on soil forming and geomorphic processes. Surficial geologic mapping by F. H. Swan and J. A. Whitney was used extensively along with U.S. Geological Survey Map I-855-G by Colton. Soil Conservation Service maps of Larimer and Weld Counties were also used to distinguish specific soil types within each geologic group. The

REFERENCES

INDEX MAP

COLORADO

SCALE 1:48,000

CONTOUR INTERVAL 100 FEET

DOTTED LINES REPRESENT 50-FOOT CONTOURS

APPROXIMATE MEAN DECLINATION, 1973

Adapted from base by U.S. Geological Survey, Front Range Urban Corridor Project

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.

SHALLOW SURFICIAL MATERIALS

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D.C. Shelton and W. P. Rogers, Colorado Geological Survey

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

40° 37' 30"

ENV. GEOL. 6-C
1975

EXPLANATION

These general comments do not reflect specific geologic or other important factors which will be present.

20% +

Steep Slopes -- generally suitable for recreational, agricultural, or open-space use. Unstable slopes may prevent all but costly, carefully engineered construction.

10% - 20%

Moderate to Steep Slopes -- generally suitable for the above uses. Back slope instability may be a problem, therefore, foundations, cuts, and fills for roads and buildings must be carefully engineered.

5% - 10%

Gentle to Moderate Slopes -- generally suitable for most uses. Some restrictions relating to drainage, erosion and construction may be present.

1% - 5%

Gentle Slopes -- generally suitable for all uses.

0 - 1%

Very Gentle Slopes -- suitability is restricted by the nearly ubiquitous high groundwater table and/or poor surface drainage.

DISCUSSION

This slope map is a graphic representation of the topography of the land surface. Slope should be considered in the design and location of buildings, site grading, revegetation, transportation routes, utility lines, landfill sites, and general excavations, as well as slope stability evaluation, drainage, and flood control. Slope is only one of many physical considerations and should be analyzed in conjunction with geologic, hydrogeologic, and engineering data. Different land uses have different slope requirements or constraints. For example, a housing development, a mountain recreational complex, a major transportation corridor, and a solid-waste disposal site each require different slope conditions for proper siting and construction. These constraints may affect general feasibility, cost, drainage, and other critical aspects of a given project.

The five slope categories used on this map are generalized and as such indicate the predominant slope. Slope areas that are steeper or gentler than the mapping category may be included in that category when such areas are too small to be depicted at the 10-ft contour interval of the topographic base map from which the slope map was compiled. Therefore, although this map should be sufficiently accurate for land-use planning, it should not be used for individual site analysis or design purposes.

REFERENCE

Mohorich, Leroy, 1972, Slope analysis of the Windsor Study Area: Colorado Geol. Survey open-file rept.

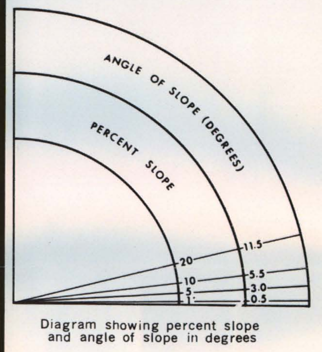
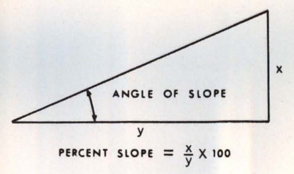
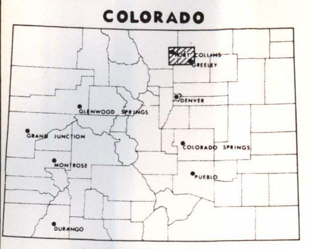


Diagram showing percent slope and angle of slope in degrees





INDEX MAP

ADAPTED FROM BASE BY U.S GEOLOGICAL SURVEY, FRONT RANGE URBAN CORRIDOR PROJECT

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.

SLOPE ANALYSIS
WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, COLORADO GEOLOGICAL SURVEY

SCALE 1:48,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS

22° 30"

104° 37' 30"

APPROXIMATE MEAN DECLINATION, 1973

ENV. GEOL. 6-D
1975

EXPLANATION

Major drainage basin divide

Drainage basin divide

Minor drainage basin divide

Area prone to flooding

Generalized direction of flow

DISCUSSION

This map shows the drainage basins and areas of past flooding as interpreted by James P. Walsh (1973). The delineation of the drainage basins is based on U.S.G.S. 7 1/2' topographic maps, stereographic aerial photos, and field investigations. Areas of past flooding have been interpreted from the examination of aerial photography, field examination and interviews with local residents.

This map does not attempt to outline the 100-year flood limits as defined by the U. S. Army Corps of Engineers and other quantitative methods. The map does show all areas that exhibit evidence of past flooding either on air photos or upon field inspection.

The magnitude and type of flooding vary throughout the study area. Small, steep watersheds tend to flash flood in relatively narrow areas adjacent to the channels, whereas the major rivers with their wider flood-plain development are subject to much more extensive flooding as a result of longer periods of precipitation and/or snowmelt.

This map can be used by planners to determine the direction of flow of surface water, the approximate area of basins and subbasins, and the ultimate routing of runoff to a major stream. Areas that exhibit evidence of past flooding will be susceptible to flooding in the future.

Man-made structures, such as bridges, culverts, roadways, and other structures within the floodway, can profoundly affect the extent and severity of flooding. Debris such as trees, shopping carts, trailers and tires can significantly affect flood drainage by blocking any constriction that may be present. All construction in areas of possible flooding should take into account both the possible hazard to the structures, and the impacts of the proposed construction on the floodway itself.

REFERENCE

Walsh, J. P., 1973, Drainage basins and areas of past flooding in the Windsor area, Colorado. M.S. Thesis, University of Colorado, 36 p.

NOTE: See text for additional information

INDEX MAP

ADAPTED FROM BASE BY U.S GEOLOGICAL SURVEY, FRONT RANGE URBAN CORRIDOR PROJECT

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

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DRAINAGE BASINS AND AREAS OF PAST FLOODING
WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, COLORADO GEOLOGICAL SURVEY

SCALE 1:48,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS

APPROXIMATE MEAN DECLINATION, 1973

ENV. GEOL. 6-E
1975

EXPLANATION

Symbol	Land use
1	Residential
2	Commercial
3	Services
4	Industrial
411	Surface extraction
413	Crude petroleum and natural gas extraction
513	Airport
7	Public and quasi-public facilities
74	Educational facilities
8	Parks and recreation
921	Irrigated farmland
922	Non-irrigated farmland
93	Animal production, including feedlots
95	Pasture, grazing land
2/3	Combination of uses, i.e., 2/3 - commercial and services

Irrigation ditch

NOTE: The areas and numbers on this map are modified after Land Use Maps of the Poudre Triangle prepared in the Department of Geography, University of Colorado by Donald D. MacPhail and others. Number designations are based on the Land Use Classification Manual (1966) which presents numerical listings of land uses that are grouped into ten basic categories. These groupings are made primarily on the basis of the function or activity performed on the land.

DISCUSSION

The land-use areas designated on this map are based on 1970 air photos and thus reflect the land use at that time with only slight modifications resulting from field checking in 1972. The fact that the mapping shows two-thirds of the land in irrigated farming reflects the strong agricultural base of the area. The problem of the agricultural community interacting with a growing urban and industrial community is a complex problem for the citizens and planners of the Fort Collins-Greeley-Loveland-Windsor Area.

REFERENCES

Inter-County Regional Planning Commission (now the Denver Regional Council of Governments) Land use classification manual, 1966.

MacPhail, D. D., and others, 1972, Land use maps of the Poudre Triangle: University of Colorado, Department of Geography, unpub. maps.

INDEX MAP
COLORADO

APPROXIMATE MEAN DECLINATION, 1973

ADAPTED FROM BASE BY U.S GEOLOGICAL SURVEY, FRONT RANGE URBAN CORRIDOR PROJECT

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
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EXISTING LAND USE
WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

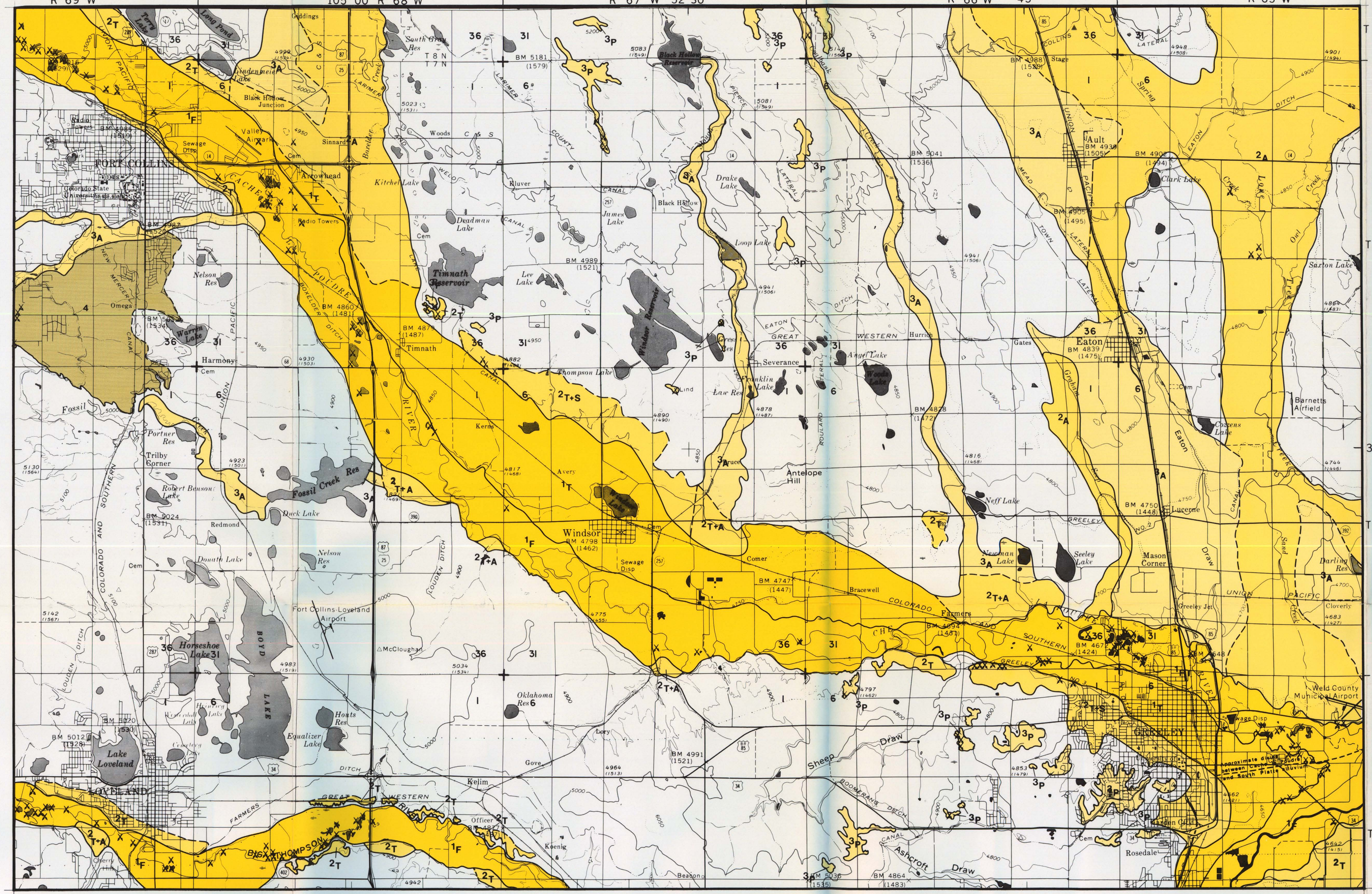
By D. C. Shelton and W. P. Rogers, COLORADO GEOLOGICAL SURVEY

SCALE 1:48,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

ENVIRONMENTAL GEOLOGY No. 6-F



ADAPTED FROM BASE BY U.S. GEOLOGICAL SURVEY
FRONT RANGE URBAN CORRIDOR PROJECT

SCALE 1:96,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

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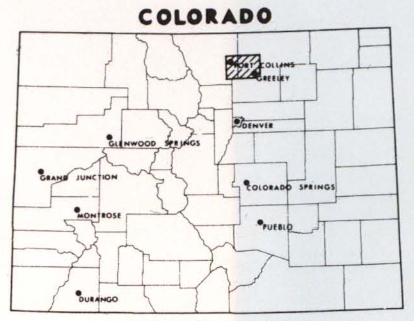

INDEX MAP

SAND AND GRAVEL RESOURCES

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, Colorado Geological Survey

1975

13° 22.5'
TRUE NORTH
MAGNETIC NORTH

APPROXIMATE MEAN DECLINATION, 1973

EXPLANATION

(Deposit quality ratings; 1 best - 4 poorest)

1 — *Highest quality and most economic sand and gravel resource. Generally suitable for use in portland cement concrete with minimal processing.*

1_F — *Sand and gravel found in the approximate geologic flood plain of the major streams. Generally 5 ft of overburden and at least 10 ft of resource. In the natural state, the ground water is usually within 8 ft of the surface, and thus the gravel pit operators usually must drain the pit or use a dragline.*

1_T — *Sand and gravel located in low terraces above the present flood plain. Quality slightly more variable than "1_F" due to increased weathering and caliche; generally, however, a high-grade resource. Overburden thickness greater than "1_F" but usually within current economic limits, whereas, resource thickness may be greater than "1_F".*

2 — *Good quality aggregate but more variable and unpredictable than "1" due to one or more of the following factors: a) weathering, b) type of source material, c) fines, d) caliche, e) overburden, and f) thickness. Found generally on high terraces of the major streams and flood plains and on low terraces of streams that do not have a nearby source in igneous terrain.*

2_T — *Sand and gravel found on old stream terraces. Lower quality than "1_T" due to weathering and caliche.*

2_{T+S} — *Same as "2_T" but with slope wash added, causing local increases in fines and overburden.*

2_{T+A} — *Same as "2_T" but with addition of class "3" or "4" quality alluvial deposits*

2_A — *Sandy and gravelly valley fill along smaller tributaries entering the Cache la Poudre valley from the north. Quality varies but may be comparable to "1_F" when overburden-to-resource ratio is favorable (or low).*

3 — *Marginal resource. Sand and gravel with extensive caliche found on old pediment surfaces.*

3_p — *Generally not suitable for concrete aggregate but valuable locally for fill and base material.*

3_A — *Marginal resource due to overburden thickness.*

4 — *Poor quality resource found on pediment surface southwest of Fort Collins and consisting of highly weathered incompetent rock. Generally has red color and highly variable quality, grading and quantity. Quality decreases to the east.*

X — *Sand and gravel pit.*

DISCUSSION

Aggregate materials are basic to the construction and maintenance of highways, roads, houses, hospitals, schools, dams, and most major projects. Other important uses include sewage treatment, water filtration, landscaping, manufacturing, and petroleum production. Sand and gravel are the major constituents of portland cement concrete and asphaltic concrete. The average consumption per capita per year in Weld and Larimer Counties is approximately 10 tons. This map shows the distribution and relative quality of the alluvial aggregate resources of the study area.

Within a given map unit, local variations in quantity and quality do exist as a result of the complex geologic processes of deposition. This map can be used as a general planning and exploration guide but not for individual site analysis. The problems and potentials associated with reclamation of mined land should be considered in the local planning process. With proper planning, conflicts can be avoided, and the benefits of multiple-sequential land use may be enjoyed by all citizens.

REFERENCES

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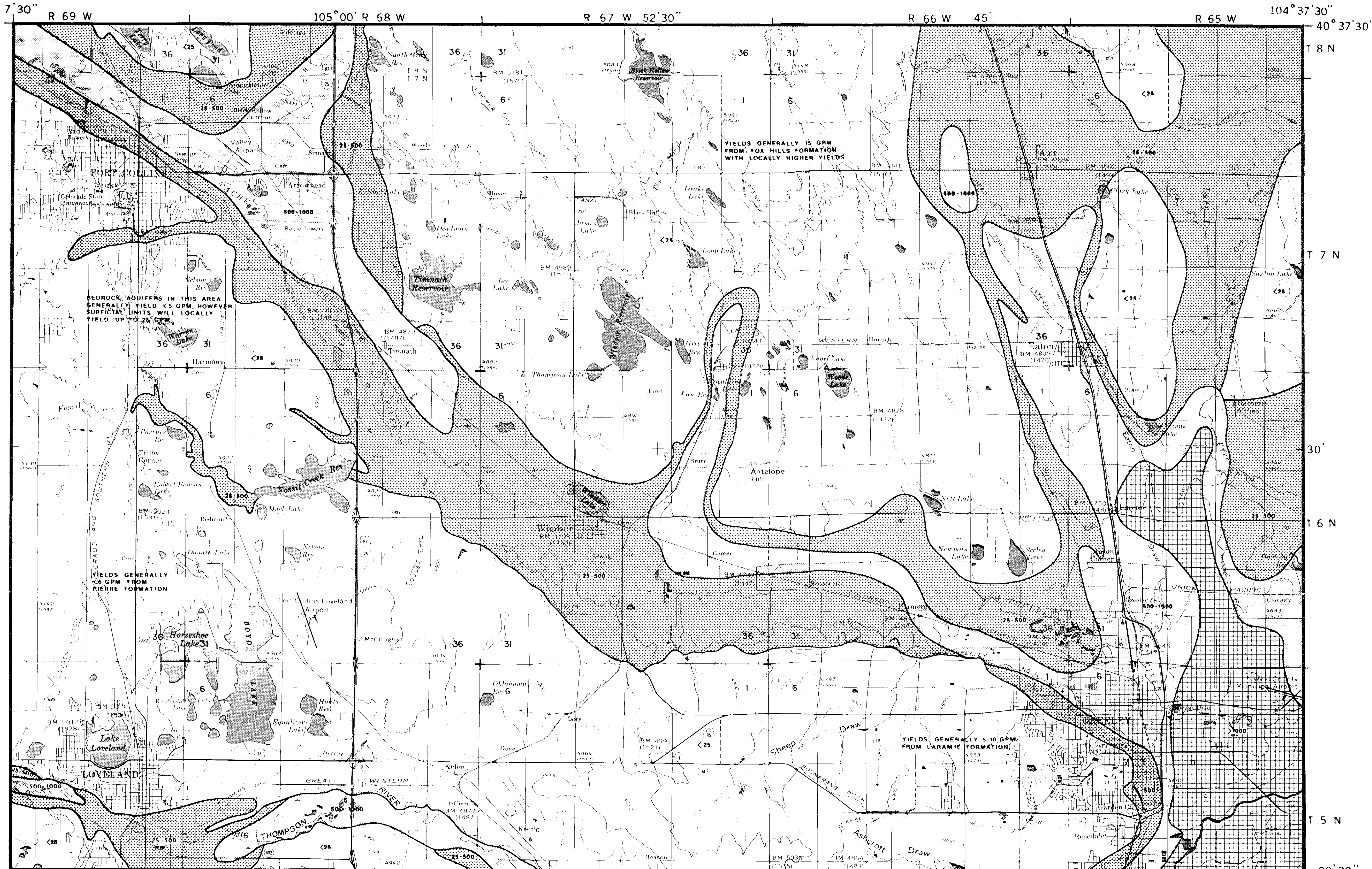
DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR



ADAPTED FROM BASE BY U.S. GEOLOGICAL SURVEY FRONT RANGE URBAN CORRIDOR PROJECT

SCALE 1:96,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.

EXPLANATION

Generalized probable yields in gallons per minute

- <25
- 25-500
- 500-1000
- >1000

DISCUSSION

The yields of water wells shown on this map are approximate. These yields may vary substantially as a result of local changes in aquifer characteristics and the construction of the well. Although ground water is available throughout most of the study area, the yields will differ significantly depending on the geologic unit. The shallow alluvial (unconfined) aquifers, found along the major stream courses, yield the largest quantities of water (up to 2000 gpm), and the bedrock (confined) aquifers yield smaller quantities (generally 0 to 15 gpm).

The potential yield of a well tapping an unconfined aquifer depends on the hydraulic conductivity (the ability to transmit water) and the saturated thickness of the aquifer. As a result, the highest yields are obtained from the saturated, highly permeable, thick sand and gravel deposits in the major valley fills. Yields generally decrease as the distance from the major streams increases. These lower yields are caused by a decrease in saturated thickness and, to a lesser degree, a decrease in hydraulic conductivity. Similarly, potential yields from bedrock aquifers depend on hydraulic conductivity, thickness of aquifer, and hydraulic gradient. In general terms this means that a sandstone will be a better aquifer than a shale due to the greater capacity of the sandstone to transmit water.

The recharge regime for unconfined and confined aquifers differs as do many of their other hydrologic characteristics. Unconfined aquifers are recharged vertically from the ground surface and are thus directly linked to surface hydrologic conditions. In the study area, the alluvial aquifers respond very quickly to seasonal variations of surface water and to precipitation, with the most important change apparently related to the irrigation season. For example, the water table rises markedly during the summer months as a result of seepage from irrigation ditches and of the irrigation of cropland.

Bedrock aquifers obtain water in two ways. First, where the bedrock units crop out west of the study area, water percolates directly into the bedrock. Second, water percolates through the overlying material into the bedrock at a slow rate over large areas. Therefore, recharge to confined aquifers occurs very slowly with no short-term, direct link to the surface water conditions.

REFERENCES

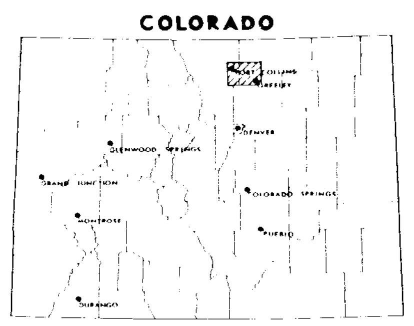
Briscoe, H. J., Jr., 1972, Stratigraphy and aquifer characteristics of the Fox Hills sandstone in the Greeley area, Weld County, Colorado: Colorado School Mines, Master Sci. Thesis T-1456, 78 p., 7 pls.

Colorado Division of Water Resources, 1973, Well data: Colorado Div. Water Resources unpub. data.

Hershey, L. A., and Schneider, P. A., Jr., 1964, Ground-water investigations in the lower Cache la Poudre River Basin, Colorado: U. S. Geol. Survey Water-Supply Paper 1669-X, 22 p., 3 pls.

Woodward, Dennis, 1972, A hydrogeologic investigation of the Cache la Poudre River alluvium in the Windsor triangle area, Colorado: Colorado Geol. Survey open-file rept., 63 p.

COLORADO



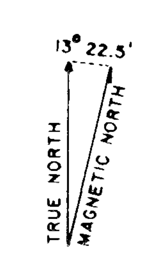
INDEX MAP

GROUND WATER AVAILABILITY

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, Colorado Geological Survey

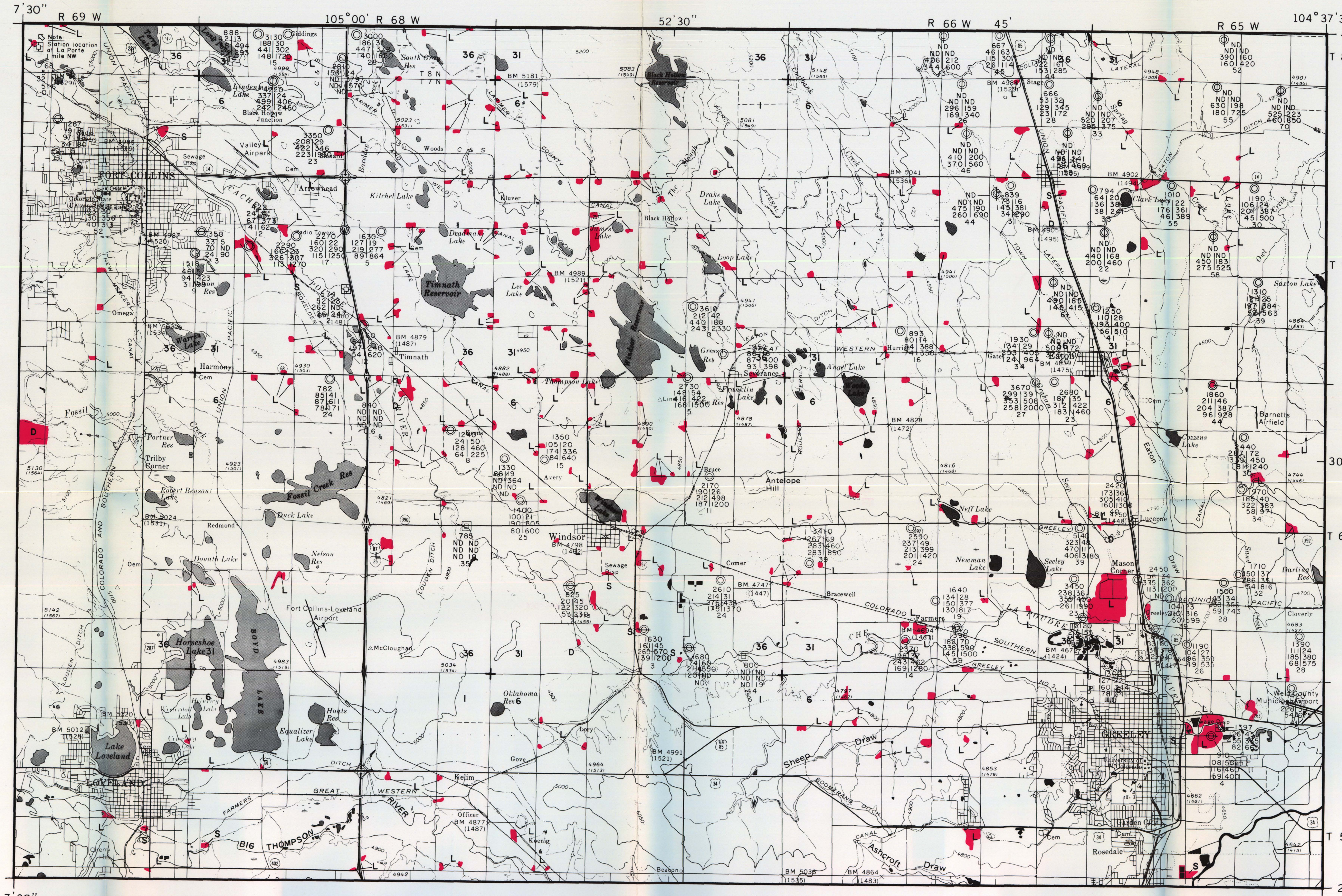
1975



APPROXIMATE MEAN DECLINATION, 1973

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

ENVIRONMENTAL GEOLOGY No. 6-H



ADAPTED FROM BASE BY U.S. GEOLOGICAL SURVEY
FRONT RANGE URBAN CORRIDOR PROJECT

SCALE 1:96,000

1/2 0 1 2 3 4 5 MILES
4000 0 4000 8000 12,000 16,000 20,000 24,000 28,000 FEET
1/2 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

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EXPLANATION

SURFACE WATER QUALITY DATA
(Source and year of collection)

- Colorado State University (1972)
- Environmental Protection Agency (1972)

ALLUVIAL GROUND WATER QUALITY DATA
(Source and year of collection)

- Edgerton (1972)
- Illgner (1972)
- Schneider and Hershey (1960)

CHEMICAL WATER QUALITY SYMBOL
(Values in mg/l; ND means "no data")

total dissolved solids

sodium + potassium	chloride
calcium	bicarbonate
magnesium	sulfate

nitrate

The map symbol for the example is:

1680

174	60
211	550
120	ND

ND

Example:

One sample collected had the following analysis:

- total dissolved solids - 1680
- sodium + potassium - 174
- calcium - 211
- magnesium - 120
- nitrate - no data
- sulfate - no data
- bicarbonate - 550
- chloride - 60

POTENTIAL SOURCES OF POLLUTION

- L - livestock concentration
- S - sewage treatment plant and/or lagoon
- D - solid waste disposal site

(based on McPhail, 1972)

DISCUSSION

This map serves as a data base from which an understanding of the water quality regime in the Windsor study area can be obtained. Where sufficient data are available, 8 parameters of water quality are shown. Due to the variable time of sample collection, not all the data collected by the above sources (see references) can be directly correlated with each other. Ground-water samples were collected by Schneider and Hershey in 1960, while Illgner and Edgerton each collected data in the summer of 1972. EPA surface water data are average values for the period 1970-1972 while the CSU data were collected in November 1972 by Dr. S. M. Morrison. These data are plotted on the map with no attempt at relating one data point with another. Direct correlations can be made, however, with data from any single source.

The natural trend for total dissolved solids (TDS) in the surface waters to increase in the downstream direction holds true for the Windsor study area. No clear trend is shown by the ground-water quality data. Sources of dissolved solids are both natural and man-made. In an uninhabitated drainage basin, an increase in TDS would be expected as the result of chemical weathering of the soils and rocks exposed to the air and water. The man-made sources are superimposed upon this natural geochemical system and can cause significant local increases in dissolved solids. These local increases may become less significant through dilution and/or natural filtration, adsorption and aeration.

Known potential sources of contaminants that may be important to water quality are shown on the map and include livestock concentrations, sewage treatment plants, and solid-waste disposal sites. The locations for these sources are based on McPhail (1972) and on field observation. All of these potential sources of pollution can affect both the surface and the ground waters. Surface water may be affected continuously by the effluent from a sewage treatment plant. Large quantities of salt may enter streams from roads after salt has been applied to melt snow and ice. Rainfall may result in contaminated runoff from livestock concentrations, landfill sites, and city streets.

Ground water may be contaminated by water percolating through the soil in association with all of the above potential sources of pollution. In addition, agricultural fertilizers may contribute to the degradation of surface and ground waters. The effect of a contaminant on the ground water depends on the type, the quantity, and the concentration of the contaminant; the depth to ground water; and the direction and velocity of ground-water flow.

Present ground-water quality in the study area is sufficiently poor that most ground water is not fit for human consumption. Drinking water standards determined by the U. S. Public Health Service (1962) are as follows:

Chemical constituent	*Recommended limit for domestic use, in mg/l.*
total dissolved solids	*500*
chloride	*250*
sulfate	*250*
nitrate	*45*

This map shows very few locations where either surface or ground water is of a quality suitable for domestic use. In many locations, the water is also unsuitable for livestock.

If the water quality is to be maintained or improved, an understanding of the water quality regime is imperative so that each component can be properly evaluated. The water resources of the study area may well be the most important future resources and, therefore, should be understood and managed wisely.

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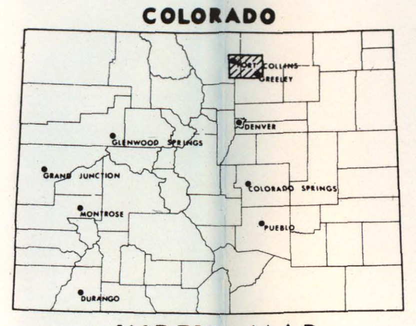


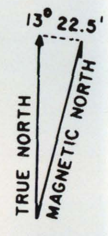
INDEX MAP

WATER QUALITY and SOURCES OF POTENTIAL POLLUTION

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, Colorado Geological Survey

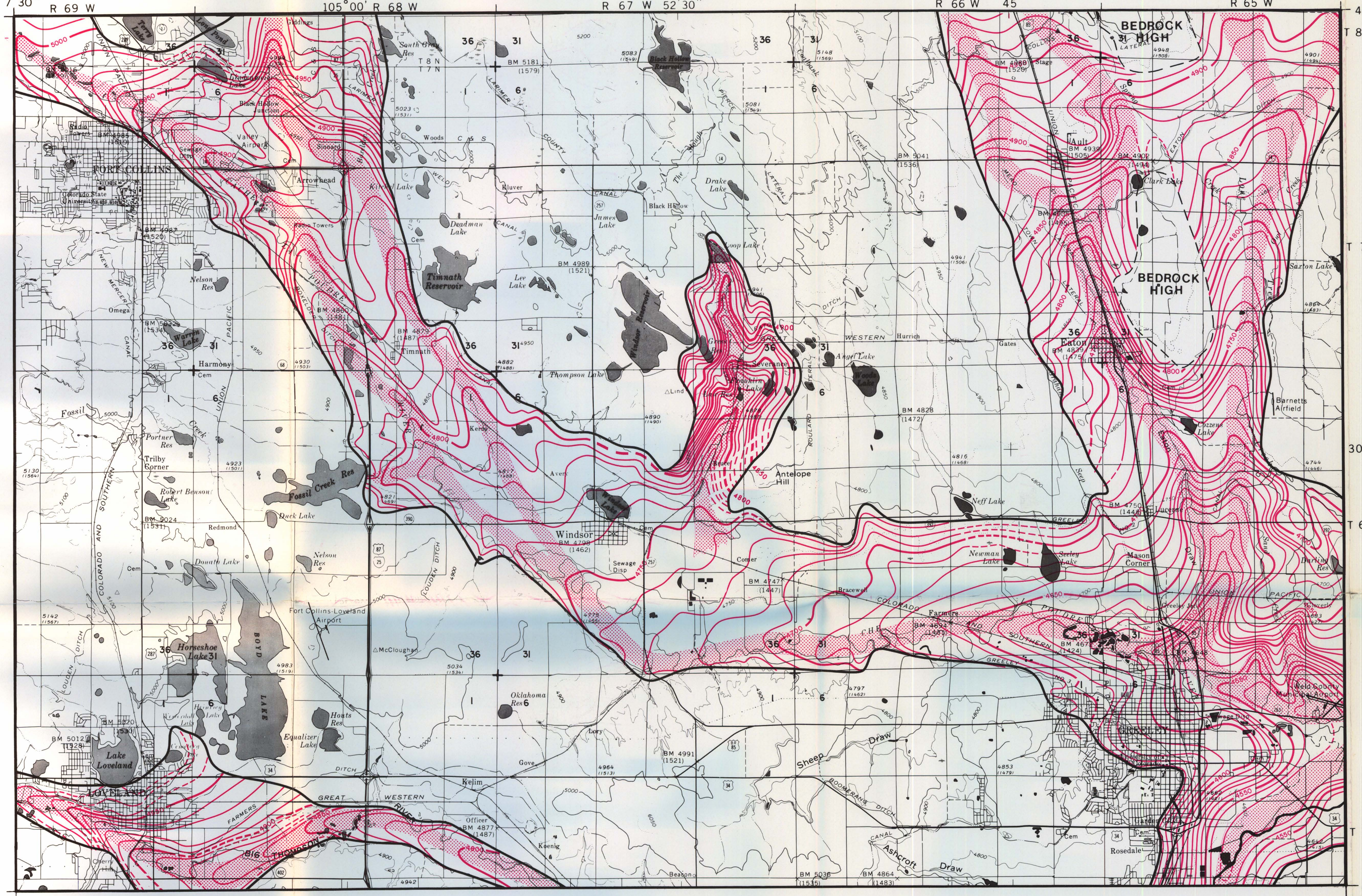
1975



APPROXIMATE MEAN DECLINATION, 1973

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

ENVIRONMENTAL GEOLOGY No. 6-I



7'30"

ADAPTED FROM BASE BY U.S. GEOLOGICAL SURVEY
FRONT RANGE URBAN CORRIDOR PROJECT

SCALE 1:96,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.

EXPLANATION

4750

Bedrock Contour
(dashed where approximate)

Shows altitude of bedrock surface above mean sea level.
Contour Interval 10 ft.

Boundary of study area

Ancient channels in bedrock surface

DISCUSSION

The Pleistocene and Recent geologic history of the Windsor study area has resulted in extensive, thick deposits of gravel, sand, and silt in the major stream valleys. This alluvial material conceals the configuration of the underlying bedrock surface on which the streams once flowed. This map shows the configuration of the bedrock surface as it would look if the alluvial material were removed. The elevation contours show the old stream valleys that were cut into the bedrock during a period when erosion was dominant over deposition. The valley fills shown on the Bedrock Geology Map (Plate 6-A) were deposited after the erosional period during times when the stream regime was primarily depositional.

In conjunction with the map showing Thickness of Unconsolidated Material (Plate 6-J), this map can be used to identify the trends of maximum thickness of alluvial deposits. This permits the identification of optimum sites for ground-water resources and for sand and gravel resources. Movement of water through the alluvium is, in part, related to the shape of the relatively impermeable, older bedrock surface over which the water flows. Maximum yields from water wells will be obtained from that portion of a given aquifer with the greatest saturated thickness. Similarly, the quantity and quality of sand and gravel resources are closely related to old channels in the bedrock. In general then, the value of alluvial ground-water resources and sand and gravel resources will increase near the deeper channels in the bedrock surface.

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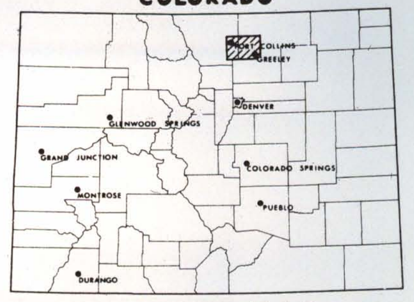
COLORADO



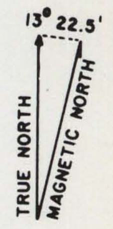
INDEX MAP

BEDROCK SURFACE TOPOGRAPHY OF VALLEY - FILL AREAS

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, Colorado Geological Survey

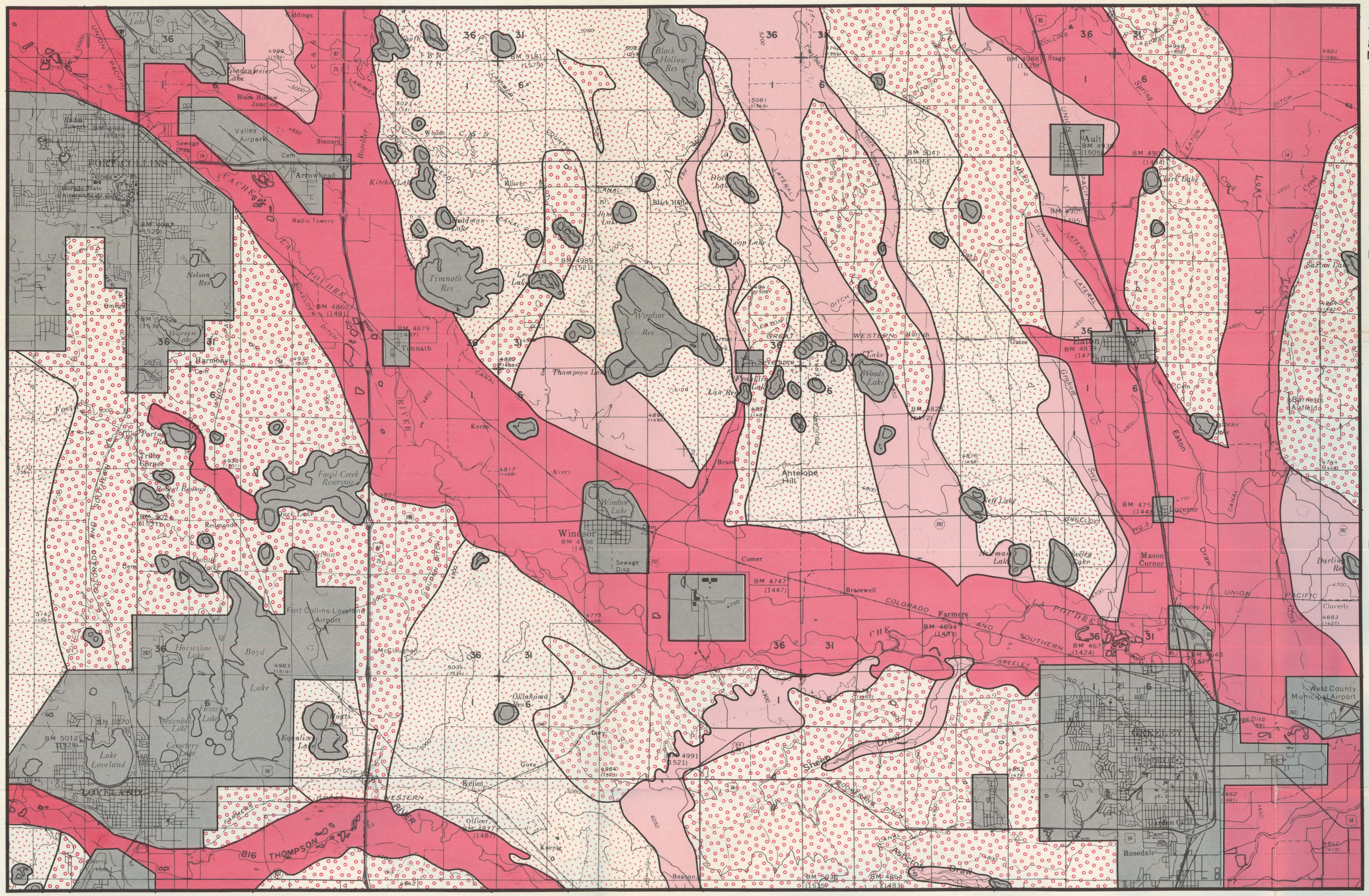
1975



APPROXIMATE MEAN DECLINATION, 1973

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

ENVIRONMENTAL GEOLOGY 6-J



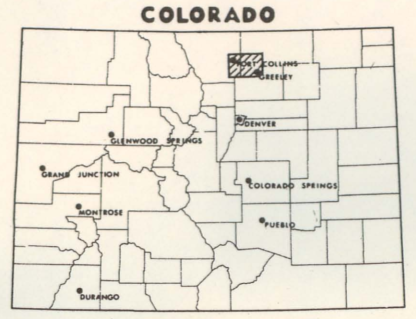
7'30" Adapted from base by U.S.G.S. Front Range Urban Corridor Project

104°37'30"

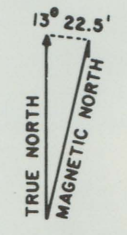
SCALE 1:96,000

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.



INDEX MAP



APPROXIMATE MEAN DECLINATION, 1973

SOLID WASTE DISPOSAL SUITABILITY

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D. C. Shelton and W. P. Rogers, Colorado Geological Survey

1980

EXPLANATION

High Suitability - areas of favorable geotechnical conditions, minimum environmental impact, and most favorable cost of operation.

Moderate Suitability - areas that may require supplemental geotechnical and engineering studies and mitigation techniques to prevent adverse environmental impacts.

Low Suitability - areas not recommended unless a comprehensive evaluation of all factors demonstrates feasibility and cost effectiveness.

Unsuitable - areas where physical conditions are sufficiently adverse as to render disposal operations unfeasible.

Preempted - areas not considered for siting due to present land uses including residential, light industrial, lakes, reservoirs, and airports. Land use data for this determination is based on 1970 air photos and field checking in 1972.

DISCUSSION

The need for new solid waste disposal sites is increasing with the rise in both population and solid waste generation per capita. In the Windsor Study Area, the 400,000 people predicted by the year 2000 will be producing approximately 730,000 tons of solid waste annually.

This map is designed as a geotechnical aid for locating future disposal sites where they will create minimal environmental degradation and risk to public safety. Its purpose is to reduce the possibilities for ground and surface water contamination and avoid potentially hazardous accumulations of methane gas. Minimizing conflicts with future land use planning has also been considered. This map does not constitute a recommendation that any area be used for solid waste disposal, it only indicates relative suitability from a geotechnical perspective.

The suitability ratings shown on this map are derived from the following geotechnical factors critical to the successful operation and long-term isolation of a solid waste disposal site:

1) compatibility of present and future land use on and adjacent to a proposed site.

2) availability of sufficient quantities of suitable materials to cover waste on a daily basis and for permanent disposal.

3) presence of relatively impermeable bedrock or surficial deposits to provide a dry environment for permanent waste storage and to restrict contamination of ground water by leachate.

4) ability to isolate the proposed site from high-yield ground water aquifers and areas of ground water recharge.

5) proximity of site to bodies of surface water that may become contaminated by subsurface seepage or during periods of flooding.

6) topographic suitability to reduce surface water runoff problems while maintaining easy access and operational conditions.

The above factors may be applied as general guidelines for evaluating the suitability of a specific proposed site for solid waste disposal. More detailed investigations of these factors are necessary before final site selection is completed. Additional considerations needing evaluation include: 1) type of waste material to be disposed of, 2) residential and industrial areas to be served and their proximity to proposed site, 3) accessibility to major transportation routes, 4) political boundaries, 5) potential for multiple, sequential land-use programs, 6) difficulty of excavation of cover materials and bedrock, 7) direction of strong winds which may redistribute waste before it can be covered, 8) comprehensive plans for future land use changes.

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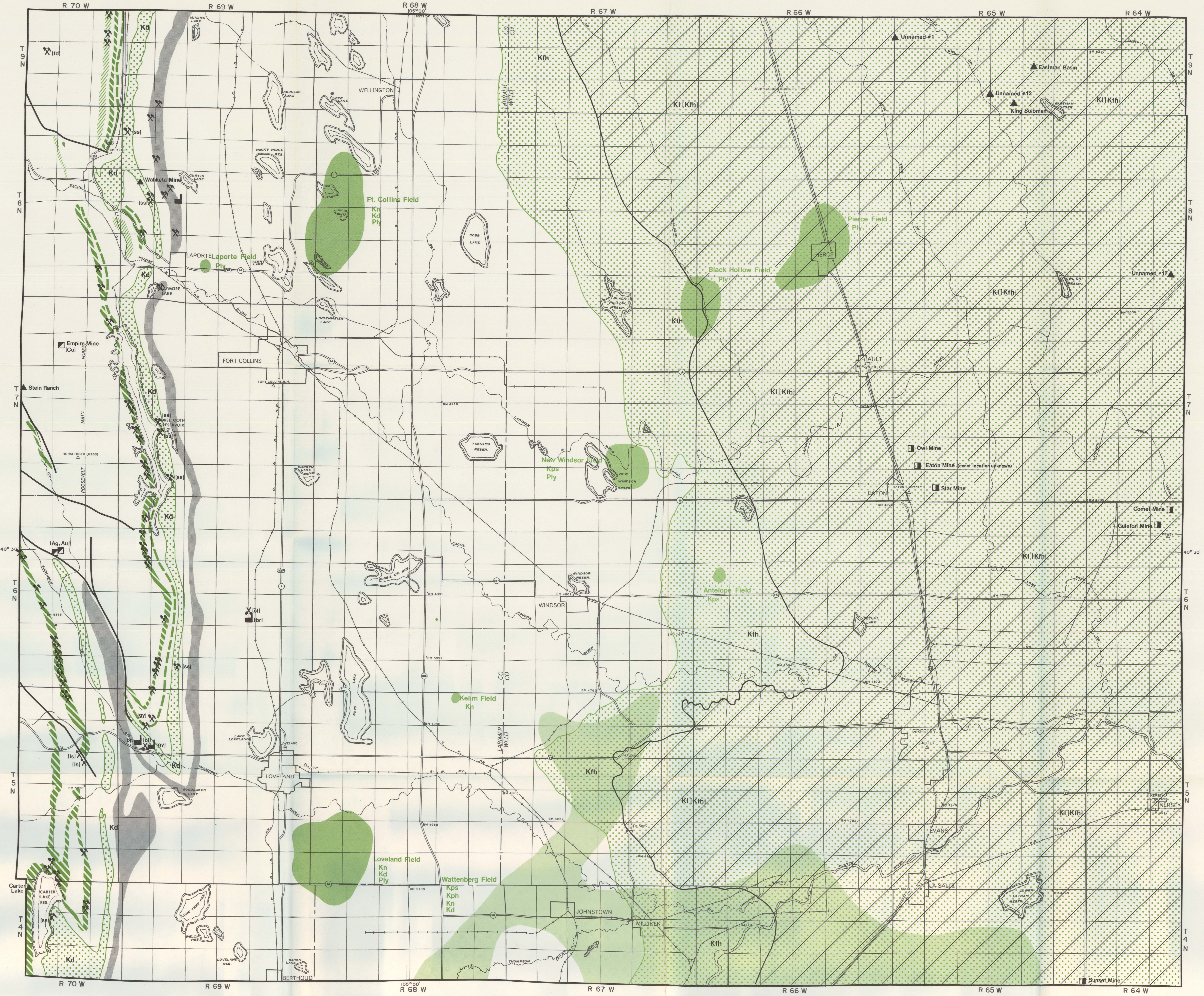
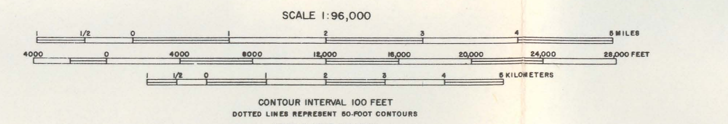
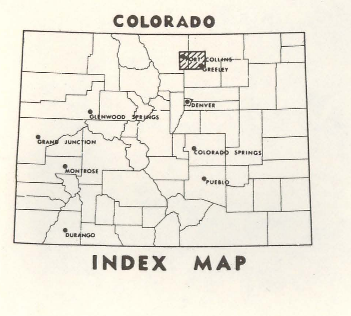






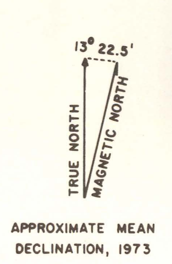
ENERGY AND MINERAL RESOURCES
[EXCLUDING SAND AND GRAVEL]

WINDSOR STUDY AREA, LARIMER AND WELD COUNTIES, COLORADO

By D.C. Shelton and W.P. Rogers, Colorado Geological Survey

1980

This map was prepared as part of the Environmental Geology Study of the potential growth areas in the vicinity of Fort Collins, Greeley, Loveland, and Windsor, Colorado. The project was funded jointly by the State of Colorado and the USGS Front Range Urban Corridor Project, Grant No. 14-08-0001-G-41.



APPROXIMATE MEAN DECLINATION, 1973

EXPLANATION

MINERAL FUELS

- oil field, with name and producing horizon(s)
- gas field, with name and producing horizon(s)

Oil and gas producing horizons:

Kps	Pierre Shale, Sussex Sandstone Member	Cretaceous
Kph	Pierre Shale, Shannon Sandstone Member	
Kn	Niobrara Formation	
Kd	Dakota Group	
Ply	Lyons Sandstone	Permian

- Areas with limited potential for coal development (Cretaceous Laramie Formation).
- Areas with potential for yielding uranium; includes Cretaceous Dakota Group (**Kd**), Laramie Formation (**Kl**), and Fox Hills Sandstone (**Kfh**).
- abandoned underground coal mine
- radioactive mineral occurrence

METALLIC

- mine shaft

Mine symbols:

Ag	silver
Au	gold
Cu	copper

INDUSTRIAL ROCKS

- Source areas for cement raw materials, quarried from Fort Hays Limestone and Smoky Hill Shale Members of the Niobrara Formation (Cretaceous).
- Source areas for gypsum used in plaster, cement materials, as decorative stone and agriculture soil conditioner; quarried from gypsum bed of lower Lykins Formation (Triassic-Permian), represented by dashed line.
- Source areas for sandstone used as dimension stone and crushed rock; quarried from Lyons Sandstone (Permian).
- Source areas for high-calcium limestone; quarried from Ingleside Formation (Pennsylvanian-Permian).
- quarry (due to map scale, symbol may represent more than one quarry)
- clay pit
- processing plant

Plant and quarry symbols:

br	brick
cl	clay
cm	cement
fd	feldspar
gy	gypsum
ls	limestone
ss	sandstone

- Location of major normal fault affecting resource bearing units

DISCUSSION

This map is a compilation of the existing and potential resources in and around the Windsor Study Area. It excludes sand, gravel and water resources as these are described on plates G and F in this series. The map base encompasses a larger region than other maps in this series in order to include additional resources that are important to future growth in the Fort Collins-Greeley-Loveland vicinity. Evaluation or development of any specific mineral resource in this area will require more detailed investigations to determine the location, quality, and extent of the resource and its potential impact to Larimer and Weld counties.

The purpose of this map is to provide critical resource information for the development of successful land-use planning. This awareness can minimize conflicts between rapid urban growth and utilization of available resources. The development of each resource needs to be evaluated both for its economic benefits and its possible detrimental impacts to the environment. Successful land-use planning will allow for both localized mineral extraction and continued development of new urban communities.

Nine oil and gas fields are located within the study area. As of January 1979, total cumulative production from these fields was 26,208,908 bbls. of oil and 4,586,120 mcf of gas. The most productive zones for petroleum accumulation have been the Lyons Sandstone, the "J" Sandstone of the Dakota Group, and the Shannon and Sussex Sandstone Members of the Pierre Shale (formation names and production figures are taken from the Colorado Oil and Gas Commission's 1978 book of oil and gas statistics). Environmental impacts vary with the scale and location of drilling operations and producing wells. New road networks, derricks, and pumps are the most visible effects. Siting of additional pipelines to transport oil and gas needs to be considered carefully to avoid excessive surface disturbance. Precautions should also be taken to prevent contamination of local water supplies by placing nonperforated well casing through the major aquifers. In general, the development of oil and gas does not constitute a major conflict with other land uses due to the limited ground disturbance.

Coal in the area lies within the Cheyenne Basin and has been mined from lower zones in the Cretaceous Laramie Formation. Six known abandoned mines produced about 15,500 tons of coal between 1883 and 1942 (Kirkham, 1978). Coal beds of the Cheyenne Basin generally are thinner and of poorer quality than those found to the south in the Denver Basin. For this reason the prospect for future coal development in the Windsor Study Area is not as great as for areas to the south. In most of the eastern part of the study area, the top of the Laramie coal beds is expected to be within 200 ft of the surface (Kirkham and Ladwig, 1979). The shallow depth of these zones would discourage underground mining due to subsidence and safety risks, but might justify surface mining. The presence of valley-fill deposits, as shown on plate 6-A of this series, may in turn limit surface mining due to technological and economic problems related to land reclamation. Other potential environmental problems associated with coal extraction include both visual impacts and quality/quantity impacts to the Larimer-Fox Hills aquifer which is a major water source in the Windsor Study Area.

Several occurrences of radioactive minerals have been discovered in and around the Windsor Study Area. In the west, the Stein Ranch Mine has produced uranium from Precambrian pegmatite and coarse-grained granite. The nearby Wahketa Mine has produced uranium from sandstones of the Dakota Group which may yield additional deposits to the north and south. In the northeast, sandstones of the Fox Hills Sandstone and Laramie Formation have produced uranium and hold potential for future in-situ solution mining in the eastern half of the study area.

Nonmetallic resources are numerous, particularly in the foothills west of Loveland and Fort Collins. The most productive formations are depicted on the map, however, potential from other units also exists. The following is a general summary of the sedimentary deposits capable of producing future nonmetallic resources (information has been derived primarily from U. S. Geol. Survey Misc. Inv. Ser. Map I-965, by Crosby).

Laramie Formation (Cretaceous) - Currently provides most of the structural clay within the Front Range Urban Corridor and may be the largest potential source for the future. Clay of low-grade refractory quality may be present in lower units of the formation; some lower sandstones of the Laramie can be used in brick to control shrinkage during firing.

Pierre Shale (Cretaceous) - Thickest of clay producing rocks in the urban corridor. Future technological improvements may allow use of Pierre in making brick with lower firing temperatures and less fuel than with materials currently used. Shale units of the Pierre may become a future source of expandable shale which when processed results in a product with two or three times the volume of the original material, high structural strength and valuable thermal and acoustical-insulating properties.

Niobrara Formation (Cretaceous) - Smoky Hill Shale and the Fort Hays Limestone both contribute constituents important to the manufacturing of cement. In localized areas of the northern urban corridor, the Smoky Hill is also a low grade oil shale. The Fort Hays may be quarried additionally for foundry limestone and agricultural or mortar lime.

Benton Shale (Cretaceous) - Noncalcareous shale at the base of the formation may yield clay for brick and small amounts of pottery clay. The Benton is also considered a potential source of expandable shale for lightweight aggregate.

Dakota Group (Cretaceous) - Sandstone from the South Platte Formation has been quarried for building stone, riprap and landscaping rock. It has also been utilized in foundry work and as a silica additive in cement.

Lykins Formation (Triassic and Permian) - Beds in the lower part of the Lykins are a primary source for gypsum in the northern urban corridor. Lykins limestone has been used for decorative stone and agricultural lime and mortar. Economic quantities of gypsum are found primarily north of the Big Thompson River.

Lyons Sandstone (Permian) - Quarried for dimension stone and crushed rock.

Ingleside Formation (Pennsylvanian and Permian) - Source of high-calcium limestone used in sugar refining, metallurgical processes and other industrial needs. Economic quantities of limestone are found primarily north of the Cache la Poudre River.

In addition to these sedimentary deposits, nonmetallic resources may also be produced from the local igneous and metamorphic rocks. Pegmatities can be a source for small amounts of quartz, feldspar and mica. Some low to moderate quality nonreactive crushed rock may be quarried from local gneiss.

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