EXISTING CONDITIONS: SOILS

KOTZEBUE AIRPORT RELOCATION FEASIBILITY STUDY

PROJECT NO. 61317

31 OCTOBER 2007

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KOTZEBUE AIRPORT RELOCATION FEASIBILITY STUDY

1.0 INTRODUCTION

The Alaska Department of Transportation and Public Facilities (DOT&PF) has initiated a project to update the master plan for the airport at Kotzebue; a coastal city and regional transportation and commerce hub located on the northwest tip of the Baldwin Peninsula, in northwest Alaska (Figure 1; Drawings A-01 and A-02).

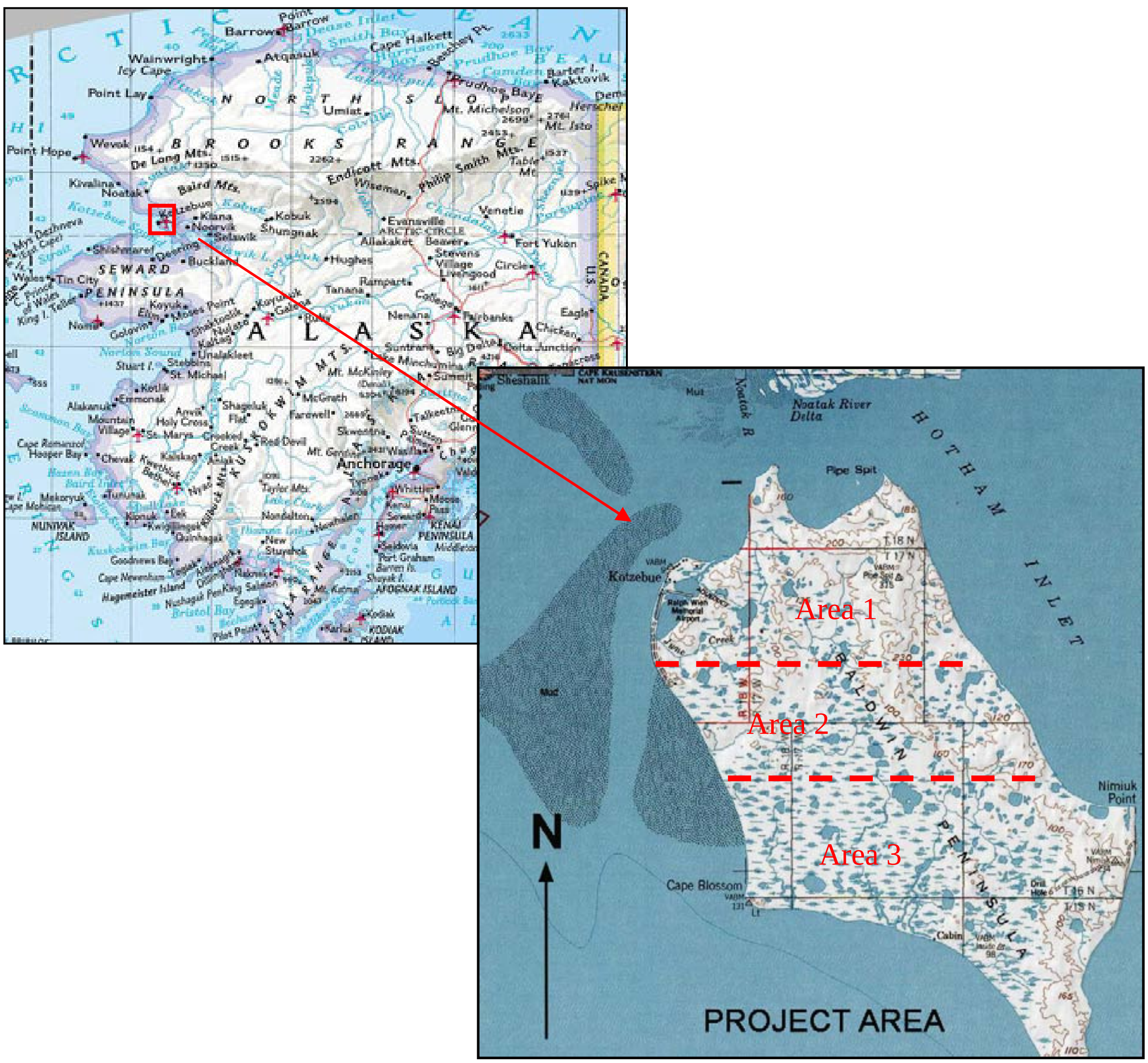

FIGURE 1: PROJECT LOCATION

In August 2005, the DOT&PF contracted PDC Engineers, Inc. (PDC) for professional services associated with Stage I of the master plan update; which entails a multi-task study to examine the feasibility of relocating the airport elsewhere on the Upper (northern) Baldwin Peninsula, as an alternative to improving and expanding the current airport infrastructure. PDC in turn retained R&M Consultants, Inc. (R&M) to provide the geotechnical services associated with the Kotzebue Airport Relocation Feasibility Study project (*Agreement for Professional Services* dated 12 September 2005). At this time, the DOT&PF has authorized work on Tasks 1 (*Project Startup and Administration*), 2 (*Public Involvement*), 3 (*Issues & Existing Conditions Assessment*), 4 (*Aviation Forecast, Alternative Development and Analysis*), and 5 (*Site Recon and Feasibility Study {Scoping} Report*).

This *technical appendix* summarizes R&M's findings from our work to-date, which has been limited to:

- An office study of existing geologic and geotechnical data culled from R&M, DOT&PF and City of Kotzebue project files, as well as other publications available in the public domain; and,
- A limited visit on 30-31 August 2006, by Mr. Peter Hardcastle (R&M Senior Engineering Geologist), and representatives of DOT&PF, Kikiktagruk Inupiat Corporation (KIC), NANA, Maniilaq Association, PDC and their other subconsultants, which included helicopter over-flights and landings to observe general surface conditions across the project area and at several potential material source sites.

Section 2 summarizes preliminary interpretations of the physical geography of the Upper Baldwin Peninsula, including geomorphology and climate, geology and seismicity, permafrost, and general soil units. Section 3 reviews known and potential sources of coarse-grained materials, aggregate and rock throughout the Kotzebue Sound region. And Section 4 provides preliminary geotechnical considerations relative to relocating and conceptual planning of a new airport.

NOTE:

At the time of this summary, no specific airport relocation sites have been defined; instead, PDC divided the project area into three general areas (see Figure 1 and Drawing A-03). The discussions hereafter focus on the airport relocation, versus improvements at the existing airport. And, no geotechnical explorations (e.g. test borings, test pits, sampling or laboratory testing) have yet been performed specific to this study.

2.0 PHYSICAL GEOGRAPHY

2.1 Geomorphology and Climate

The Baldwin Peninsula is a narrow land feature, of about 150 to 175 square-miles, bounded on the west by Kotzebue Sound, off the Chukchi Sea, and on the east by Hotham Inlet (Drawings A-01 and A-02). This peninsula is interpreted to be a terminal moraine, created at the end of a pre-Wisconsin glacial advance (e.g. Hamilton, 1994; and Huston et al., 1990), but is not currently glaciated. The peninsula is situated in the *Kobuk-Selawik Lowlands* physiographic division, characterized by rolling, lake-dotted lowlands with gently sloping hills to about 350 feet in elevation, and surrounded by coastal, wave-cut bluffs and a narrow beach (Wahrhaftig, 1965). Surface drainage from the peninsula generally flows to the west, into Kotzebue Sound, following June Creek, Sadie Creek, Riley Creek and two or more other unnamed courses east of Cape Blossom. The project area is generally covered with moist to wet tundra vegetation (AEIDC, 1975).

The Upper Baldwin Peninsula experiences a transitional climate (AEIDC, 1975), with generally moderate *maritime* conditions in the summer (e.g. mild temperatures with more precipitation), but more severe *continental* conditions in the winter (e.g. extreme cold temperatures with less precipitation). Table 1 summarizes the general temperature and precipitation data recorded at Kotzebue. Note that the climate data specific to airport design (e.g. winds, day light, icing conditions, cloud cover, etc) will be developed for this project by others.

TABLE 1: KOTEZBUE CLIMATE DATA[1]

Mean Annual Air Temperature, °F	21.8
Mean Monthly Temperature, °F January / July	-2.5 / 54.7
Record Daily Air Temperature, °F Low (February 1968) / High (June 1991 & July 1957)	-52 / 85
Mean Annual Precipitation, in.	10.05
Mean Monthly Precipitation, in. Min (May) / Max (August)	0.33 / 2.00
High Monthly Precipitation, in. (August 1998)	5.26
Mean Total Snowfall, in. Annual / Max Monthly (November & December)	49.4 / 8.8
High Total Monthly Snowfall, in. (November 2003)	45.6

[1] http://climate.gi.alaska.edu/Climate/Location/West/Kotzebue.html. “Mean” parameters are from the period 1971 to 2000; while the “record” and “high” parameters are from the period 1949 to 2004.

2.2 Geology and Seismicity

The surficial geology of the Upper Baldwin Peninsula is comprised of variable marine, estuarine, glaciomarine and glacial sediments (e.g. Hamilton, 1994; and Krause, 1985), over mid to late Tertiary sandstone, conglomerate and shale, early Tertiary volcanic rock, and Pre-Tertiary metamorphic rock (e.g. Decker et al., 1988; and Kirschner, 1994). There are no bedrock outcrops on the peninsula and the depth of unconsolidated surficial deposits is unknown; although: a test well drilled at Kotzebue in the early 1950s to a depth of 326 feet did not encounter bedrock (Williams, 1970); and Decker et al. (1988) reported at least 190 feet of "sand, silt and clay" over an Early Pleistocene, possibly marine, stratum (bedrock?)[2] of "…silt, and mud with common pyritized wood-fragments…" to a depth of 1,180 feet in an exploration well drilled (mid 1970s?) near Nimiuk Point, on the east side of the peninsula. Bedrock underlying the low mountains surrounding Kotzebue Sound has been mapped as schist and phyllite, limestone, sandstone and conglomerate, granitic, and basalt (e.g. Dumoulin and Till, 1985; Kaufman, 1986; Patton, 1967; Patton and Miller, 1968; Sainsbury, 1974; and Smith, 1913).

This region of Alaska is characterized by moderately-low seismicity. The closest mapped faults with interpreted Holocene displacements are about 110 miles south of Kotzebue (Plafker, et al., 1993). Since 1898, 13 earthquakes with ***Local Magnitude*** (M_L) greater than or equal to 5.0 have been cataloged[3] within about 150 miles of Kotzebue; the largest of these being events of M_L 6.5 (in 1950) about 130 miles to the south, and M_L 5.9 (in 1973) about 150 miles to the east; and the closest being an event of M_L 5.0 (in 1966) about 10 miles south-southwest of the City. The probabilistic peak horizontal ground acceleration (in bedrock) with a 475-year mean return period predicted[4] across the project area is about 0.08g; generated by a shallow, random M_L 5-7.3 earthquake.

2.3 Permafrost

The Upper Baldwin Peninsula is underlain by continuous permafrost (Brown et al., 1997). A test well drilled at Kotzebue in the early 1950s reported permafrost to a depth of at least 238 feet (Williams, 1970). The shallow permafrost is interpreted to contain significant volumes of ground ice, likely regardless of elevation or topography, based on a prevalence of thermokarst terrain (*topographic depressions resulting from natural and man-induced thawing of ice-rich permafrost*), and massive ground ice forms visible in many of the coastal bluffs. The shallow permafrost also appears to be moderately warm: ground temperatures measured in the bluff east of the Kotzebue Airport ranged from 28 to 32°F at a depth of 15 feet, and 28 to 30°F at a depth of 40 feet (R&M, 2004); and ground temperatures measured in a test boring near Sadie Creek, between Kotzebue and Cape Blossom ranged from about 27 to 28°F from the surface to a depth of 51 feet (MBJ, 1982).

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2 Kirschner (1994) described this stratum as a "…marine(?) sandstone conglomerate and shale."

3 http://www.giseis.alaska.edu/Seis/

4 http://eqint.cr.usgs.gov/eq/html/deaggint.html

In general, the seasonal active layer appears to be about one to two feet thick, but is likely deeper under the thermokarst lakes. Test borings drilled in two of the larger lakes on the peninsula, Devils Lake (R&M, 1989) and Vortac Lake (Quadra Engineering, 1983), both primary water sources for Kotzebue, encountered permafrost at a depth of about 48 to 50 feet.

Thermokarst Terrain

Thermokarst features are very common across the Upper Baldwin Peninsula. The most obvious and wide-spread of these features (following definitions in Davis, 2001; and NRCC, 1988) observed across the project area included:

- Numerous small to moderate sized thermokarst lakes (*a closed depression in the permafrost table, created by naturally induced thawing, filled with water*) were observed in both low and elevated rolling terrain (Figure 2); many of the latter with low slumping banks. Water depths are unknown, although many of these lakes, especially the smaller ones, are likely very shallow.

  Based on comparison of 1952 and 1978 aerial photography, MBJ (1983) concluded that the active thermokarst lakes did not appear to be growing in size, but were infilling with organics around the edges. Further, some of these lakes appeared to be migrating toward the southeast.

  Large, relatively flat areas observed across the center and western portions of the project area were interpreted to represent relic (i.e. drained) thermokarst lakes; some up to one mile or more in diameter. Up to about six feet of relief was observed along the perimeter of a large, relic thermokarst lake near Cape Blossom.

- Thaw sinks (*a closed depression in the permafrost table, created by naturally induced thawing, with subterranean drainage*) were typically observed on hills and ridges, and ranged up to 300 feet in diameter and from 10 to 40 feet deep. The outlet drainages were cut along troughs left by a melted ice wedge, along which the sides had collapsed forming subterranean channels.

  Based on comparison of 1952 and 1978 aerial photography, MBJ (1983) concluded that many of the thaw sinks they observed were growing, several almost doubling in size, while others had coalesced. Further, the banks of the thaw sinks were actively eroding, especially on the uphill side, but a few were eroding downhill and had almost daylighted. Some ridges had many thaw sinks, while others had few or none at all; although, it is unknown if this corresponds with the concentration or abundance of massive ground ice.

- Thermo-erosional niches (*recesses along stream banks or bluffs produced by thermal erosion of ice-rich permafrost*) were observed along many of the coastal bluffs bordering the project area (Figure 3).

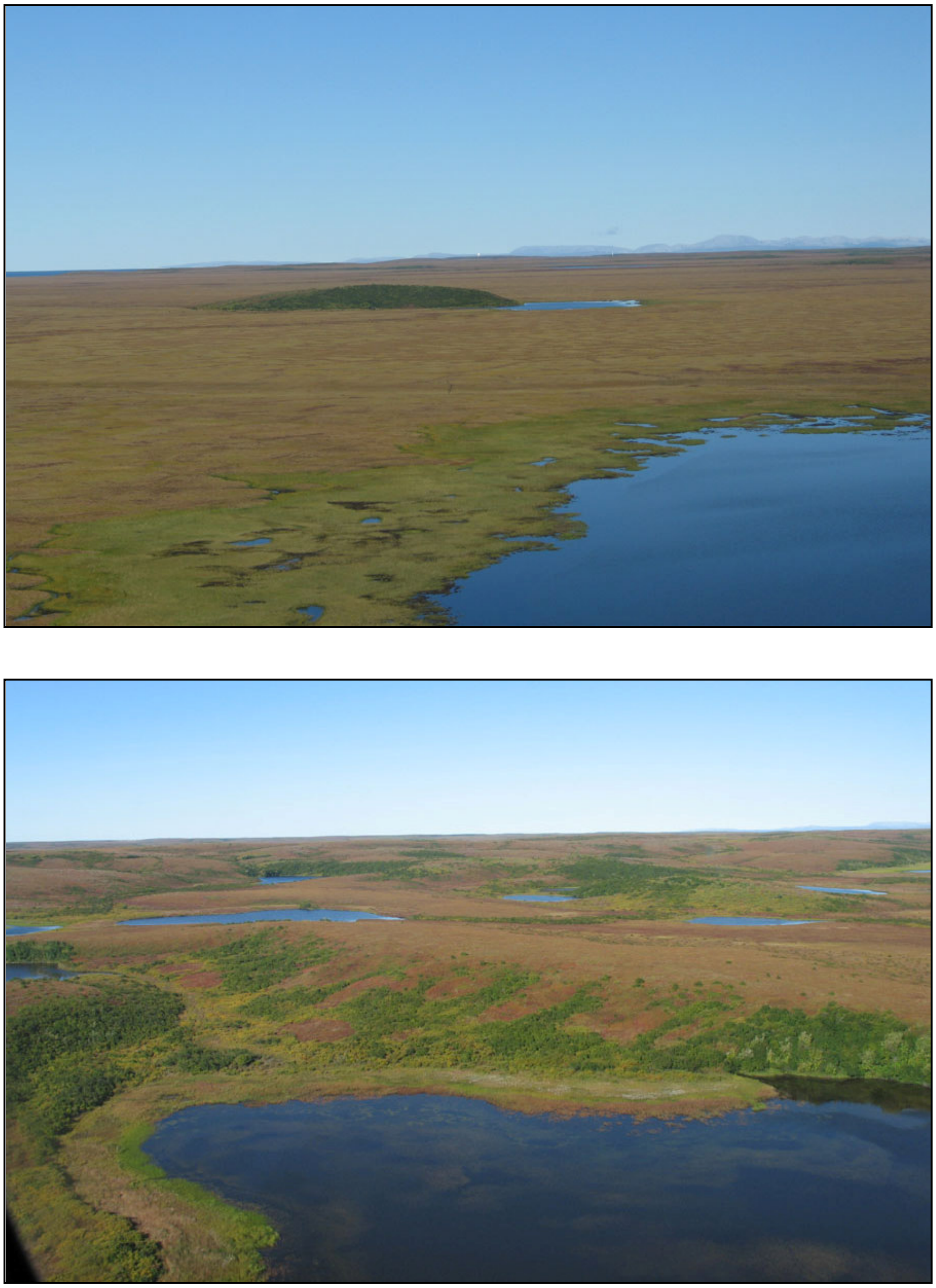


FIGURE 2: THERMOKARST LAKES
(In low terrain {upper photo} and elevated terrain {lower photo}; 30 August 2006)

FIGURE 3: THERMO-EROSIONAL NICHES
(Near Cape Blossom, 31 August 2006)

Other forms of thermokarst terrain observed, but much more limited in extent or distribution included a beaded stream (***drainage comprised of small ponds interconnected by short straight or angled channels forming along melting ice wedges***) along the upper reaches of Sadie Creek; thaw bulbs (***a more or less symmetrical area of thaw in permafrost surrounding a man-made structure***) around fill placed (mid-1970s?) for an exploration well drilled near Nimiuk Point (Figure 4); and ice-wedge casts (***former ice wedge, since thawed and filled in with collapsed or transported soil***) exposed in some of the coastal bluffs (Figure 5).

Massive Ground Ice

Shallow, massive ground ice forms (ice wedges and ice lenses) also appear to be common across the Upper Baldwin Peninsula. Polygon-patterned ground (***large, closed multi-sided ground patterns with boundaries over ice wedges***) was observed locally in several areas, including near Kotzebue, Cape Blossom and Nimiuk Point (visible in Figure 4). Numerous ice wedges have also been reported (e.g. McCulloch and Hopkins, 1966), and were observed during our site visit, in many of the coastal bluffs surrounding the peninsula (Figure 6).

FIGURE 4: THAW BULB BELOW MAN-MADE FILL
(Near Nimiuk Point, 30 August 2006)

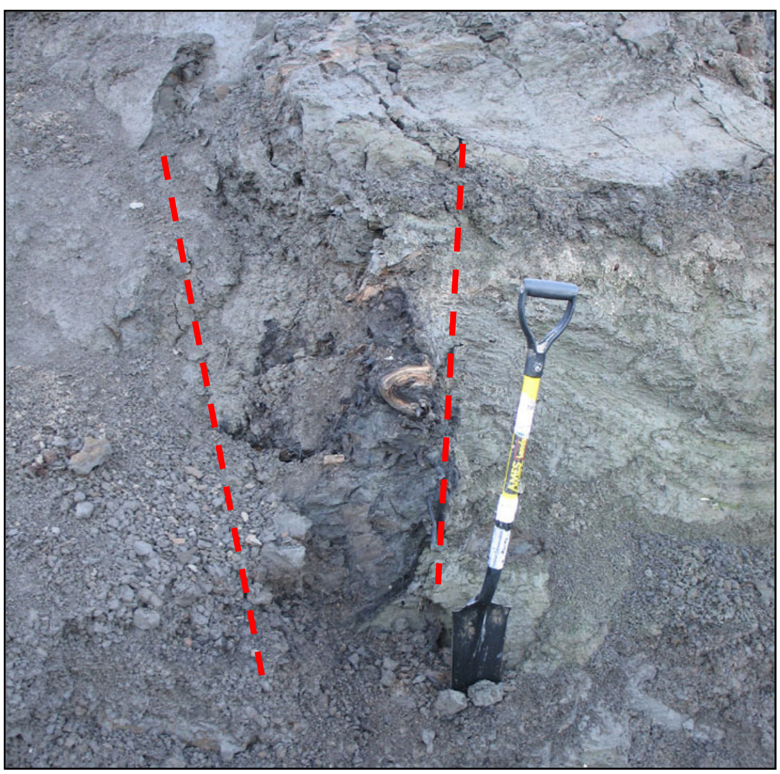


FIGURE 5: ICE-WEDGE CAST (30 August 2006)

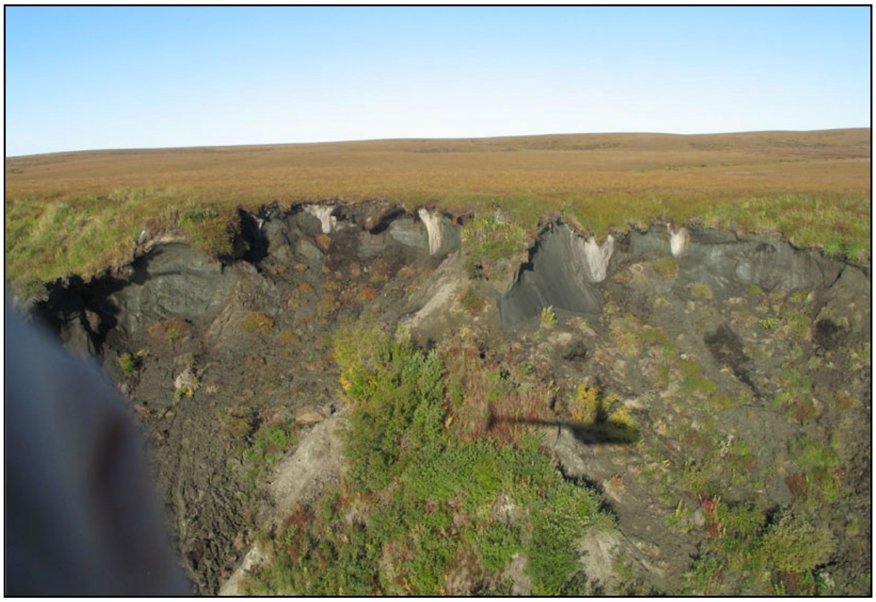


FIGURE 6: ICE WEDGES
(Eastern Coast of the Upper Baldwin Peninsula, 31 August 2006)

2.4 General Soil Units

The surficial geology of the Upper Baldwin Peninsula can be generalized as ice-rich, eolian and reworked silt or organic-rich lacustrine silt deposits, overlying variable glaciofluvial materials, overlying a terminal moraine deposit (till) formed of marine sediments pushed up by glaciers that had advanced from the east (e.g. Hamilton, 1994; and Huston et al., 1990). Much of the peninsula is surrounded by a steep coastal bluff, created by wave action cutting into the elevated marine sediments and overlying silt deposits. Recent coarse-grained beaches and spits, and fine-grained lagoon deposits have also formed along the base of the coastal bluff around much of the peninsula. Figure 7 illustrates a schematic profile of these general soil deposits.

For the purpose of this study, we grouped the surficial soil deposits into six general units, including: estuary deposits, beach deposits, lagoon deposits, upland silt, glaciofluvial deposits, and glacial till. Note that given the limited extent, and more often lack of tangible field or laboratory test data available at this time, the division between these general soil units is rather arbitrary, and was determined considering the interpreted geologic origin and index parameters (e.g. grain-size, plasticity, consistency or relative density, etc). The following summarizes the geotechnical characteristics of these general soil units, based on information culled from existing reports and literature.

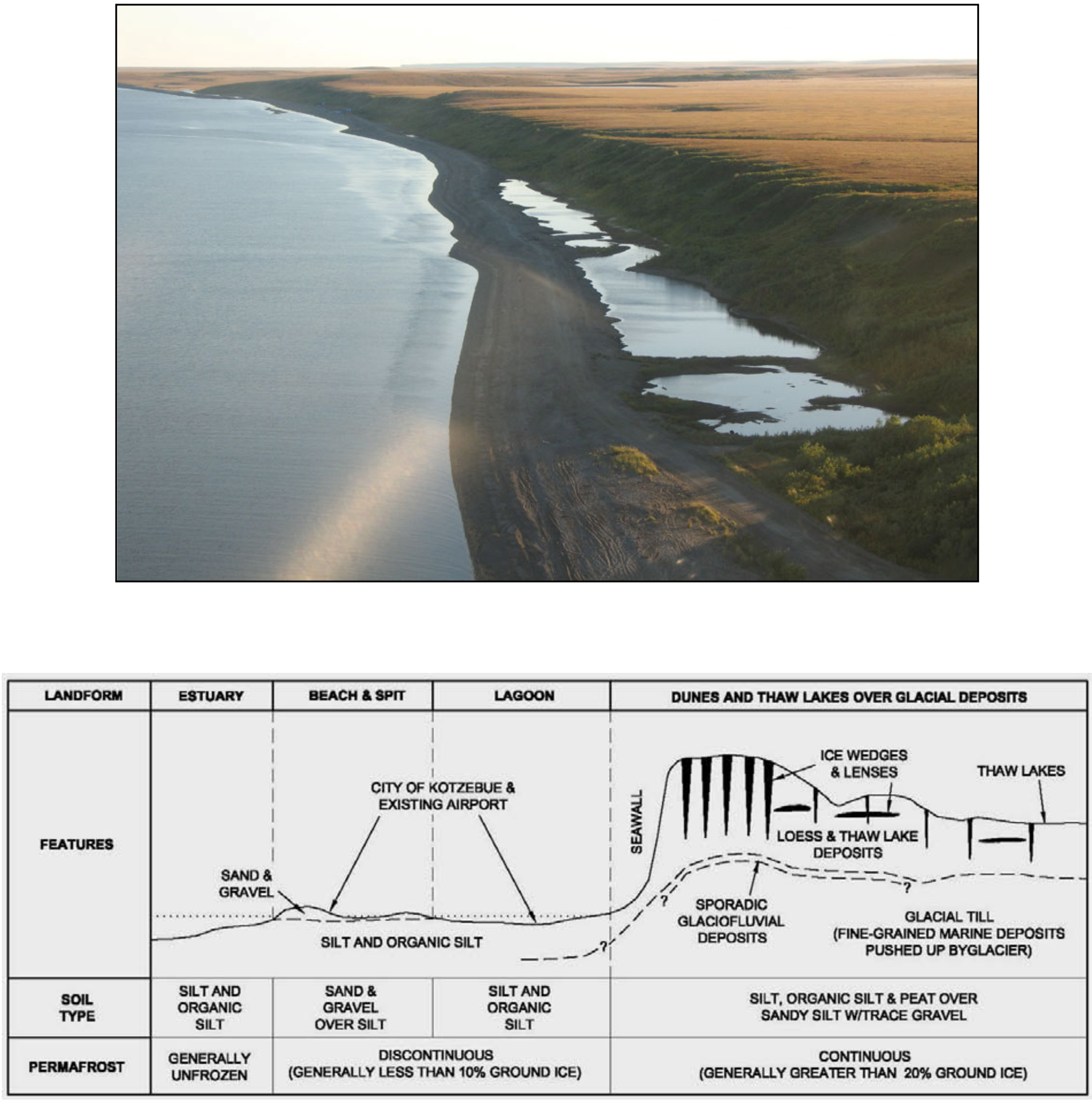


FIGURE 7: SCHEMATIC SOILS PROFILE, UPPER BALDWIN PENINSULA

NOTE: The photograph, documenting the western coastline between Sadie Creek and Cape Blossom (31 August 2006), is actually reversed in order to provide a visual perspective of the coastline matching the orientation of the schematic profile. Further, the schematic profile was cut through the existing Kotzebue Airport (R&M, 2004).

Estuary Deposits

Estuary deposits consist of the fine-grained silt and clays eroded from the coastal bluffs, and discharged from the Kobuk and Noatak Rivers. We found limited geotechnical data for this soil unit. Two test borings were drilled at about 900 and 1,900 feet west of the Kotzebue Airport which reported loose to medium dense silt and organic silt to depths of 20 feet below the seafloor (S&W, 1982). And eight test borings along the shoreline at Kotzebue, north of the airport, generally encountered medium dense silty sands to a depth of 13 to 27 feet, overlying loose silts (R&M, in progress). Permafrost was not noted in any of the test borings.

Beach Deposits

Deposits of sand and fine gravel form a beach around portions of the Upper Peninsula. These coarse-grained deposits were typically narrow and thin; although similar coarse-grained materials were reported more than one-half mile offshore of Sadie Creek and Cape Blossom (G.E.O.D.E. Exploration, 1984). The beach deposits appeared to be comprised of materials eroded from the glacial till and glaciofluvial units exposed in the coastal bluffs, and then transported by long shore currents: notable spits have formed around the Upper Peninsula at Kotzebue, Pipe Spit and Nimiuk Point. Based on limited information, the gravel particles are relatively small, and rounded to subrounded.

Past investigations at Kotzebue reported that the beach sand and gravel is about 10 to 15 feet deep, overlying silt and organic silt, with discontinuous permafrost at depths ranging from five to 10 feet (e.g. Alaska Testlab, 1974; CRCE, 1985; DOT&PF, 1990, 1992 & 1993; R&M, in progress; and TNH, 1968). An investigation by G.E.O.D.E. Exploration (1984) identified limited and sporadic sand and gravel, typically less than three feet thick, up to one-half mile offshore of Sadie Creek and west of Cape Blossom; six to 25 feet thick south of Cape Blossom; and at least seven feet thick in the beach along the south margin of Cape Blossom (see Section 3.1, below).

Lagoon Deposits

The lagoon deposits generally consisted of soft organic-rich silts and fine sands. We found limited geotechnical data for this soil unit. A single test boring drilled in the Kotzebue Lagoon, off the east end of the runway, encountered loose/soft silts and organics [which may have been fill placed to form the runway embankment], overlying silt, overlying a shallow gravel deposit at 24 feet [old beach?], overlying glacial till at a depth of about 28 feet (S&W, 1982). Additionally, six test holes drilled to a depth of 25 feet in two small islands south of the runway encountered discontinuously frozen organic silts and sandy silts (S&W, 2001).

Upland Silt

The uplands across the Upper Peninsula are likely mantled with very fine-grained, non to moderately plastic silt, including eolian, colluvium and lake (lacustrine) deposits. Locally, these silt deposits are also interspersed with amorphous and coarse organic matter; including buried layers of peat (Krause, 1985) and wood from old forests (McCulloch and Hopkins, 1966). This general soil unit is likely ice-rich, and very unstable and susceptible to rapid erosion when unfrozen.

There have been a few past geotechnical investigations that penetrated this general soil unit, mostly in the vicinity of Kotzebue. Just east of Kotzebue, several deep borings in undisturbed areas near Vortac Lake and Devils Lake encountered silt to depths greater than 50 to 75 feet (Quadra, 1983; R&M, 1989). And borings near Sadie Creek encountered silt to depths of at least 40 to 50 feet (MBJ, 1982).

Based on limited laboratory test data, materials in this general unit have typically contained less than five to 10 percent sand (0.75 to 4.75 mm) and about five to 15 percent clay-sized (smaller than 0.002 mm) particles, and up to 20 percent organics. Further, plastic index values up to almost 25 have been reported. Figure 8 illustrates a compilation of moisture contents and *Standard Penetration Test* (SPT) 'N' values (as an indication of relative density or consistency in unfrozen soils; and texture, ground ice, and temperature in frozen soils) reported in MBJ (1982), Quadra (1983) and R&M (1989 and 2004).

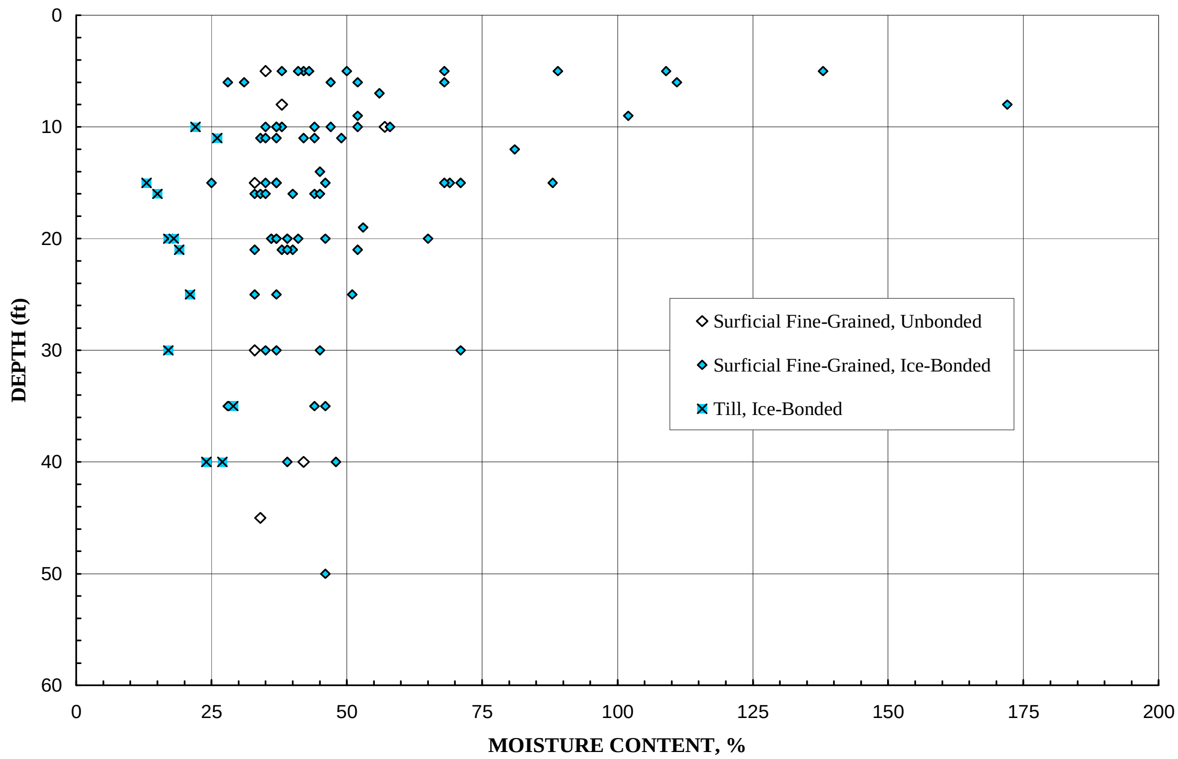
Glaciofluvial Deposits

Sporadic (discontinuous) and thin sections of coarse-grained glaciofluvial materials have been observed in the coastal bluff around the peninsula (see Section 3.1, below), sandwiched between the upland silt and glacial till units. From observation, this unit also appears to contain cobble and boulder sized materials; although, we are not aware of any tangible geotechnical information on these materials (see Section 3.1, below).

Glacial Till

This general soil unit is a heterogeneous mix of non to moderately plastic fine-grained glacial and reworked marine deposits, which is interpreted to form the core of the Upper Baldwin Peninsula. Based on very limited information, the top of the glacial till near Kotzebue may be above sea-level (R&M 2004), but may occur deeper, below sea-level, near Sadie Creek (MBJ, 1982) and along the coast on either side of Cape Blossom (McCulloch and Hopkins, 1966).

Based on limited laboratory test data, materials in this general unit have contained up to about 30 to 40 percent sand and gravel, and about 15 to 20 percent clay-sized particles. Figure 8 also includes the few moisture contents and SPT 'N' values reported in MBJ (1982) and R&M (2004) for the glacial till. Based on these data, as well as observation of exposures along the coastal bluffs and a few salinity measurements (MBJ, 1982 & 1983), we suspect the glacial till may contain much less segregated ground ice than the overlying upland silt unit.



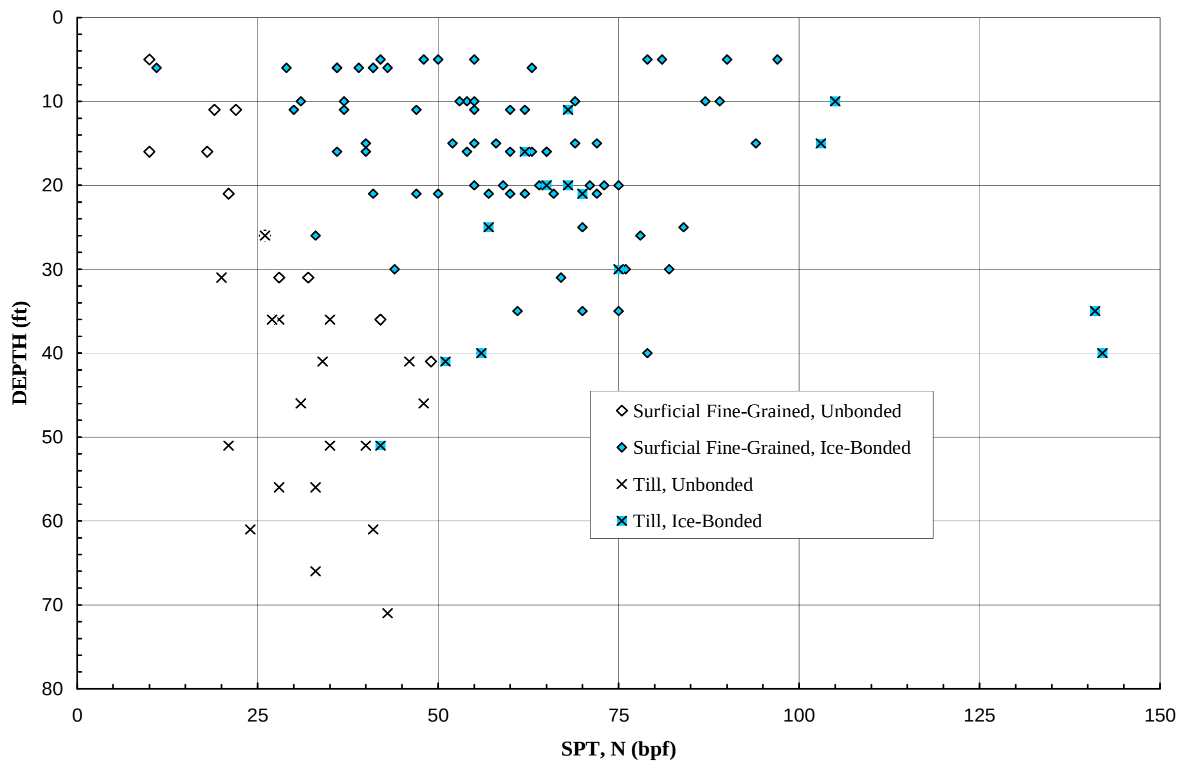


FIGURE 8: INDEX CHARACTERISTICS, UPLAND SILT AND GLACIAL TILL SOIL UNITS

3.0 POTENTIAL MATERIAL SOURCE AREAS

The following summarizes our preliminary interpretations of potential sources of coarse-grained borrow (for embankments – see Section 4.2, below), aggregate (for pavements) and stone (rip-rap for embankments {see Section 4.2, below} and erosion protection) that may be needed to support construction of a new airport on the Upper Baldwin Peninsula. Based on conceptual estimates by PDC, we understand upwards of three million cubic yards of borrow material may be required for construction of an entirely new airport, excluding the pavement section and access road to Kotzebue. Considering the significant volume of materials required, and the absence of geotechnical information away from the City of Kotzebue, we expanded our review to include potential sources around the entire Kotzebue Sound region.

Based on published information and our experience around Kotzebue Sound, Table 2 summarizes seven potential areas that we speculate may contain significant volumes of materials suitable for this project; the locations are illustrated on Drawings A-02 through A-07. Note, however, we are not aware that any of these areas have been investigated in sufficient detail to verify material types, quality or quantities, and therefore the following discussions should be considered conceptual, at best. Further, subject to the types and quantities of materials actually required, we suspect that more than one source will have to be developed (see Section 4.5, below).

TABLE 2: POTENTIAL MATERIAL SOURCE AREAS, KOTZEBUE SOUND REGION

Areas of Interest		Type of Materials Likely Present	Potential to Produce Significant Quantities
BALDWIN PENINSULA			
1	Cape Blossom	Beach Deposits: Sand, gravel and silt	Poor to Moderate
2	Northeast Coast	Glaciofluvial: Sand, gravel and silt	Poor (to High?)
OTHER KOTZEBUE SOUND AREAS			
3	Lower Noatak River	Sand, gravel and bedrock	High
4	Deering-Candle	Bedrock	High
5	Candle-Buckland	Bedrock	Moderate to High
6	Noorvik-Kiana	Sand, gravel and bedrock	High
7	Lower Baldwin Peninsula	Sand and gravel	Poor to Moderate

3.1 Upper Baldwin Peninsula

There are two general areas of interest on the Upper Baldwin Peninsula which both may produce coarse-grained material suitable for forming new embankments and possible aggregate for pavements, including beach (and offshore) deposits near Cape Blossom (*Area of Interest 1*), and the buried glaciofluvial deposits along the eastern side of the peninsula (*Area of Interest 2*). However, at this time there does not appear to be any likelihood that a rock source could be developed on the Upper Peninsula to produce aggregate or stone.

Beach (and Offshore) Deposits (Area of Interest 1)

Beach deposits of sand and gravel are interpreted along the west, south and north sides of the Upper Peninsula (Drawings A-02 and A-03), which likely eroded from glaciofluvial sediments exposed in the coastal bluffs. The most notable quantities of these materials appear in the general vicinity of Cape Blossom (*Area of Interest 1*). However, limited existing information suggests that these deposits are very thin and are underlain by marine silty sands and sandy silts, which may be variably plastic and highly organic and possibly saline. Further, development of this source could require dredging; and may pose significant environmental and coastal erosion concerns that would require extensive study, not the least including affects on the stability of the spit at Kotzebue.

MBJ (1981) considered a potential material site along the beach between Cape Blossom and the ‘neck’ of the peninsula (which they designated *KK-3*). This beach appears to be about 10 miles long and the material was described as gravel to three inches diameter, with some sand (Figure 9). The offshore extent and depth of these deposits are not known. However, G.E.O.D.E. Exploration (1984) collected samples from the beach and drilled a number of test holes up to one-half mile offshore of both Sadie Creek and Cape Blossom. Briefly, those explorations revealed limited and sporadic sand and gravel, typically less than three feet thick offshore of Sadie Creek and west of Cape Blossom (15 borings in three to 17 feet of water), and six to 25 feet thick south of Cape Blossom (three borings in seven to 17 feet of water). Further, at least seven feet of sand and gravel was found on the beach along the south margin of Cape Blossom.

Glaciofluvial Deposits (Area of Interest 2)

The eastern portion of the Upper Peninsula is elevated, with hill tops approaching 300 feet above sea level. This upland has been interpreted to represent the terminal moraine, comprised of reworked fine-grained plastic marine sediments, pushed up in front of glaciers advancing from the east. The marine and glacial till deposits are mantled by deep eolian and colluvium deposits of silt. Sporadic (discontinuous) layers of coarse-grained glaciofluvial material observed in the coastal bluff, sandwiched between the fine-grained upland silt and deeper glacial till units; *Area of Interest 2* pertains to such coarse-grained deposits along the northeastern ‘spine’ of the peninsula (Drawing A-03). While no substantial explorations have yet been completed to investigate the materials in this area, we consider this area to have the greatest potential for containing significant quantities of suitable borrow and aggregate anywhere on the Baldwin Peninsula (see Section 4.6, below).

FIGURE 9: BEACH DEPOSIT (East of Cape Blossom, 30 August 2006)

In particular, MBJ (1981) considered the potential that the high ridge between Kotzebue and Pipe Spit was cored with sand and gravel (which they designated *KK-1*).

Further, R&M observed coarse-grained materials in the coastal bluff, just south of Pipe Spit, where about 20 to 40 feet of gravel and sand was exposed in the upper half of the scarred area, covered by deep silt deposits (Figure 10). However, the lateral extent of this deposit is unknown, and the suitable materials are likely buried under several tens of feet of overburden (or more). Note that KIC reconnoitered this exposure in the fall of 2006, at which time a sample was collected which was classified (based on a sieve test) as ***well-graded gravel with sand*** (E. Norton, personal communication, 4 June 2007)

Other Sources of Limited Reserves

A number of small material sites have been developed at Kotzebue to support local construction. However, most of those sites have been depleted, or the remaining quantities of suitable borrow are of little significance relative to the needs of the subject project.

MBJ (1981) considered a potential offshore site between Kotzebue and Sadie Creek (which they designated *KK-1A*), and reported that some gravel had been mined from this offshore site, and from along the beach, in the 1970s and early 1980s. However, G.E.O.D.E. Exploration (1984) indicated the area near Sadie Creek may contain very little sand and gravel.

FIGURE 10: GLACIOFLUVIAL DEPOSIT (Near Pipe Spit, 30 August 2006)

MBJ (1981) also noted an eolian deposit of "fine to very fine sand and silt sand" on the neck of the peninsula (which they designated *KK-4*).

Nimiuk Point is a relatively large spit on the east side of the Upper Peninsula (Site *KK-2*; MBJ, 1981). Two borrow pits have been developed at this site (Figure 11), from which gravel and sand is presently being mined and barged to Kotzebue. We are not aware of any explorations which have validated types and quantities of suitable materials at this site; although, it is possible that present reserves could be depleted by the time construction actually begins on the subject project. Nonetheless, this is an area worthy of future exploration.

Finally, there is another spit on the northern tip of the peninsula at Pipe Spit (Figure 12) that reportedly contained about 60,000 cubic-yards of sand and gravel (USACE-AK, 2006).

FIGURE 11: ACTIVE BORROW PITS, NIMIUK POINT
(K.I.C/QAP Pt in foreground, and Drake Pit in background; 30 August 2006)

FIGURE 12: PIPE SPIT (31 August 2006)

3.2 Lower Noatak River (Area of Interest 3)

This area consists of the lands along the lower Noatak River, between the Cape Krusenstern National Monument and the Noatak National Preserve (Drawing A-04), about 15 to 30 miles north of Kotzebue (Drawing A-02). Of primary potential are river terrace deposits which may contain significant quantities of coarse-grained materials suitable for use as borrow and pavement aggregate. Additional suitable borrow may also be located in the glacial tills, and scattered and relatively small ice-contact deposits along the lower river. However, most of the surficial soils in this area appeared to be perennially frozen and could be challenging to mine. Further, the local bedrock is expected to exhibit poor durability characteristics and may not be suitable for production of aggregate or stone.

This area is apparently overlain by glacial tills and related glaciofluvial ice contact deposits, and covered by eolian silt deposits. River terraces or benches have been reported along the river (Smith, 1913 and DOWL Engineers, 1999) at elevations up to 1,000 feet. Bedrock outcrops are reported in the Igichuk and Milik Hills (Smith, 1913), and the lower Noatak River has cut a deep canyon exposing limestone. This bedrock has not been well mapped or described; although Smith (1913) reported recrystallized limestone, practically absent of dolomites. The area was glaciated (Manley and Kaufman, 2002), and is underlain by permafrost, likely discontinuous along the lower portions of the river (Brown et al., 1997).

The DOT&PF (1978) investigated a deposit in the Noatak River; described as a triangular 1,800 by 3,000-foot gravel bar at low water, about 25 miles from Kotzebue. The material was described as well rounded sandy gravel with a maximum size of 2.5 inches. Reportedly, this site is at the confluence of the Noatak and Agashashok Rivers, and contains up to three to four feet of gravel above the river level at low water (T. Drake, personal communication, January 2006).

G.E.O.D.E. Exploration (1984) drilled 32 test borings at a site on the highlands along the eastern edge of the Noatak River delta, divided into three small areas each separated by about one-half mile. The materials revealed in those explorations were described as predominately sand and fine gravel laid out in irregularly shaped deposits, interspersed in what appeared to be deposits of glacial till and eolian loess. G.E.O.D.E. Exploration (1984) estimated there was 148,000 cubic yards of "useable" material available at this site.

DOWL Engineers (1999) investigated two sites along the lower river for K.I.C. Two borings at *Site Two*, located between Hugo Mountain in the Milik Hills and the Noatak River (suspected elevated river terrace), encountered about 30-plus feet of alluvial sand and fine to coarse gravel over glacial till, with permafrost at a depth of 25 feet in one boring. Based on those limited explorations, DOWL Engineers (1999) estimated *Site Two* contained at least 770,000 cubic yards of coarse-grained material, and speculated that a Native Allotment to the north of the site may contain several million cubic yards of similar material; however, we understand recent explorations at that allotment have indicated there may be less volume of suitable material (T. Drake, personal communication, January 2006).

3.3 Deering-Candle (Area of Interest 4)

This area comprises several potential basalt and limestone/marble bedrock sites along the southern shore of Kotzebue Sound, between the Bering Land Bridge National Preserve and Candle (Drawing A-05), about 50 miles south of Kotzebue (Drawing A-02), which could be developed to produce suitable aggregate and stone. There is an existing quarry in basalt along the Inmachuk River about 17 miles south of Deering. Limited quantities of dredge tailings and alluvial deposits along the Inmachuk River may also provide suitable materials. However, schist interbedded with the limestone and basalt may contain some asbestos materials.

Bedrock in the area reportedly consists of schist, interbedded with limestone/marble, shale, and basalt (Sainsbury, 1974). Dumoulin and Till (1985) described limestone near Deering as a broken, closely jointed, foliated micaceous marble, metadolostone and massive marble. The highest quality marble reportedly was found along the east side of the Kugruk River. The petrology of the schist is complex with the parent rocks reportedly including slates, limestone, and ultramafic rocks. This area was not glaciated (Manley and Kaufman, 2002), and is underlain by discontinuous permafrost (Brown et al., 1997).

Limited coarse-grained alluvial materials have been found along the major creeks and rivers in the area, which have been the subject of gold mining along Candle Creek, Kiwalik River and Inmachuk River. The DOT&PF (1980b & 1986) investigated several small alluvial deposits along the lower reaches of the Inmachuk River, which reportedly contained fine gravel, less than 1.5 inches in size, and sand.

3.4 Candle-Buckland (Area of Interest 5)

This area includes numerous potential bedrock sources between Candle and Buckland (Drawing A-06), about 60 to 70 miles south-southeast of Kotzebue (Drawing A-02). Of primary potential are volcanic, basalt and granitic bedrock formations situated between Buckland and Spafarief Bay. There also may be suitable deposits of coarse-grained materials, albeit of limited extent, along the Buckland and Kiwalik Rivers, or other major drainage courses. However, the quality of the granitic rocks may not meet the requirements for use as aggregate or armor stone; and the basalt contains schist which may contain asbestos.

The geology of this area reportedly consisted of volcanic, granitic, and extensive flows of basalt with schist bedrocks, overlain by alluvial, eolian and colluvial deposits (Patton, 1967). Patton and Miller (1968) described the volcanic rocks as andesitic tuffs, breccias, and volcanic conglomerates with intercalated flows. Patton (1967) described the basalt as "nearly horizontal flows of gray to dark-red vesicular olivine basalt". This area was not glaciated (Manley and Kaufman, 2002), and is underlain by discontinuous permafrost (Brown et al., 1997).

The most prominent outcrops of bedrock are found on the west end of the Selawik Hills near Buckland; e.g. Clem Mountain about seven miles west of Buckland. Smaller outcrops can also be found on the low flanks of the Selawik Hills between the Kiwalik and Buckland Rivers. There is an existing quarry, in granitic bedrock, about five miles west of Buckland; described as “a monzonite of variable quality" (DOT&PF, 1994). Past observations by R&M indicated that most of the rock in this pit was highly weathered with pockets of fresher material (Figure 13).

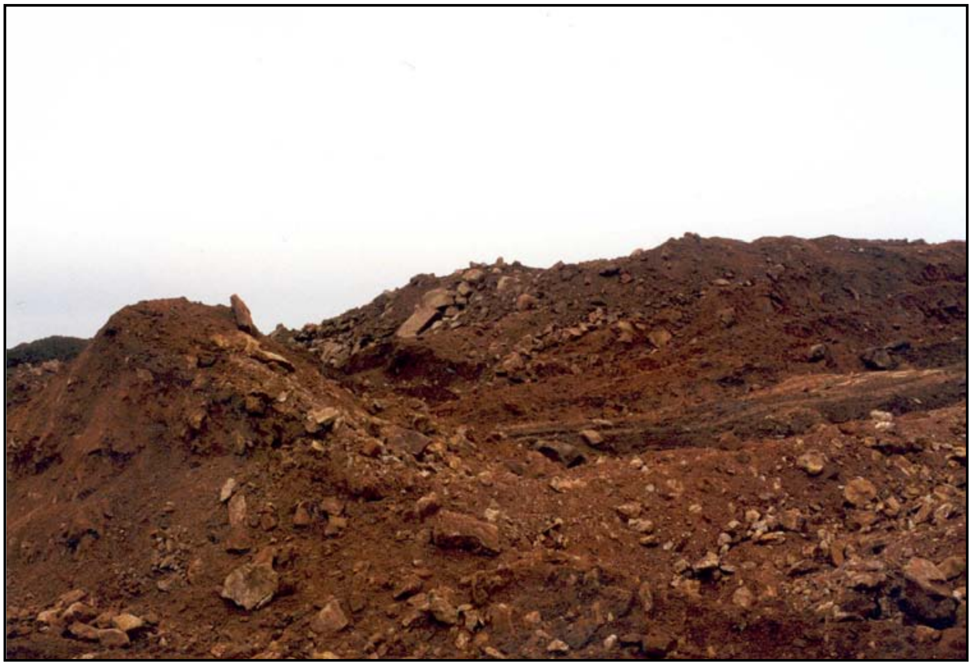


FIGURE 13: KANIK PIT, NEAR BUCKLAND (Fall 2001)

Several small alluvial gravel and point-bar deposits have been identified in the Buckland River, from which some material has been mined in the past (DOT&PF, 1980a & 1994; and MBJ, 1981); although remaining suitable reserves are probably limited.

3.5 Noorvik-Kiana (Area of Interest 6)

This area includes bedrock and coarse-grained glaciofluvial deposits along the eastern margin of Kotzebue Sound, west of Kiana and north of Kiana (Drawing A-07), about 45 to 60 miles east of Kotzebue (Drawing A-02). Of primary potential are sedimentary bedrock and coarse-grained glaciofluvial deposits near Holtham Peak, about six miles east of Noorvik. Potential schist and phyllite rock sources in the Kiana Hills may also be suitable for embankment material; although these rocks are not expected to exhibit the durability required for pavement or stone, and the schist may contain asbestos.

The geology of this area reportedly consists of glacial, alluvial, eolian and colluvial deposits surrounded by low mountains (Patton, 1967): the Kiana Hills along the north side of the Kobuk River Delta are composed of schist and phyllite rock; the Waring Mountains, which parallel the south side of the Kobuk River east of Noorvik, are composed of sedimentary rocks; and volcanic and granitic rocks, similar to those described in Section 3.4, underlie the Selawik Hills along the southeastern edge of the sound. The central and northern parts of this area were extensively glaciated, and are underlain by continuous permafrost; while the southern portion of this area was not glaciated, and is underlain by discontinuous permafrost (Brown et al., 1997; Manley and Kaufman, 2002).

Sedimentary rocks near Hotham Peak, at the west end of the Waring Mountains, have been described as non-marine conglomerate, sandstone, mudstone and coal with a volcanic and calcareous greywacke and mudstone on the eastern part of the peak. The DOT&PF (1995) considered these materials suitable for embankment fill, and the conglomerate suitable for surfacing aggregates. The DOT&PF (1995) also suggested that the bedrock on Hotham Peak may be suitable for the production of armor stone; although, two samples of rock produced degradation values of 2 and 14, and L. A. Abrasion losses of 37 and 43. A material site exists on the lower western slope of Hotham Peak (Figure 14), about six miles east of Noorvik, within a glacial outwash deposit of sandy gravel (DOT&PF, 1995).

FIGURE 14: ACTIVE BORROW SITE NEAR NOORVIK (9 August 2005)

3.6 Lower Baldwin Peninsula (Area of Interest 7)

The final area of interest includes sand and gravel beach deposits along the west coast of the Lower Baldwin Peninsula (Drawing A-07), adjacent Kotzebue Sound, between about 35 and 50 miles south-southeast of Kotzebue (Drawing A-02). The more significant volume of sand and gravel may be in the northern portion of this area; although, limited quantities of suitable materials may also be present on the Choris Peninsula (T. Drake, personal communication, January 2006). Similar to ***Area of Interest 1***, near Cape Blossom, development of these beach deposits may be restricted by hydrologic and environmental issues.

The geology of this area reportedly consists of glacial, alluvial, marine and eolian deposits (Patton, 1967). Schist and limestone bedrock has also been mapped on the Choris Peninsula. The area was extensively glaciated (Manley and Kaufman, 2002), and is underlain by continuous permafrost (Brown et al., 1997).

Of particular note is an existing gravel runway ("Arctic Landing Strip"; Figure 15), that was apparently constructed along the beach as part of the lend-lease program during World War II. This runway is about 1.5 miles long, and comprised of sand with gravel and cobbles. In addition to the above beach deposits, MBJ (1981) identified three potential sources of sand and gravel in the center of the Lower Peninsula (which they designated ***KK-5*** through ***KK-7***; Drawing A-07).

FIGURE 15: ARCTIC LANDING STRIP (View South; 31 August 2006)

4.0 GEOTECHNICAL ENGINEERING CONSIDERATIONS

The following discussions summarize basic geotechnical considerations pertinent to the feasibility of relocating the Kotzebue airport to a new site on the Upper Baldwin Peninsula. However, these discussions are very general and conceptual in nature, given that no specific airport sites have been identified, and the virtual absence of subsurface geotechnical information away from the immediate vicinity of Kotzebue. Certainly, more specific discussions will be forthcoming if the feasibility study progresses.

4.1 General Airport Siting Criteria

Away from the coastal bluff and beaches, the foundation soils across the entire project area are anticipated to be perennially frozen, rich with ground ice, extremely susceptible to thermal disturbance, and very easily eroded when unfrozen. In particular, the consequences of any thermal disturbance (i.e. thawing and or warming of the permafrost) could be expected to result in settlements (associated with thaw-consolidation, and/or secondary creep, especially in permafrost comprised of massive ice forms) that well exceed allowable surface tolerances; or bearing failures under the embankment (e.g. mass slope or lateral spreading movements). Therefore, we recommend further conceptual planning consider the following idealized criteria for selecting a potential site(s) for the new airport (see also Section 4.2, below):

- A new airport should be situated as close as possible to Kotzebue to minimize costs associated with construction and long-term maintenance of the access road;
- The foundation soil conditions should be as uniform as possible, especially under the airport pavements with strict settlement tolerances;
- Areas containing massive ground ice (ice wedges and lenses) should be avoided (however, the absence of patterned ground or thermokarst features may not necessarily correlate directly with the absence of massive ground ice[5]);
- Cuts should be avoided, especially in ground adjoining the aircraft operating areas (including for drainage); and,
- Flat terrain is preferable to rolling terrain to minimize fill quantities and to maintain a uniform fill thickness, especially along the runway (i.e. to minimize quantities and differential settlements associated with secondary creep in the underlying permafrost).

There is not sufficient information at this time to specifically evaluate the relative merits or concerns at any one site, or between alternate sites. However, based on the discussions in Section 2, we consider there could be a higher likelihood of a new airport located within Area 1 (Figure 1 and Drawing A-03) meeting or coming closer to the above idealized criteria, relative to a site in either Area 2 or Area 3 (see Section 4.3, below).

[5] McCulloch and Hopkins (1966) observed ice wedges around the Upper Peninsula truncated below the current active layer (and not obvious at the surface), which they attributed to a period of much warmer climate conditions, between about 10,000 to 7,000 years ago, when the region was forested and experienced deeper seasonal thaw.

Another potential scheme could involve relocating the new airport to an offshore site, such as the shallow coastal water between Kotzebue and Sadie Creek. Hydrologic and environmental issues aside, advantages of this scheme may include the presence of more uniform, thaw-stable foundation conditions; and more straight forward construction.

4.2 Embankment Stability

Based on the assumed foundation soil conditions and associated problems described above (Section 4.1), design of the airport and access road embankments will likely require extensive field investigation, engineering analysis and unique detailing to assure their thermal and physical stability, particularly to limit surface deformations and maintain sufficient foundation bearing capacity. However, until such time as the actual foundation conditions at a specific airport site(s) have been investigated, we recommend that conceptual planning consider that those embankments sensitive to movements be detailed as described below:

- The embankments should be formed with coarse-grained materials (rock, gravel and sand), reinforcement with multiple layers of very stiff, high-strength geosynthetics to assure physical stability relative to bearing, slope or lateral spreading failures;
- Embankment sections should incorporate rigid insulation and/or thick zones of poorly-graded stone to enhance cooling by natural convection {*air convection embankment*; Goering, 1996}, especially under the shoulders, to prevent thaw degradation and minimize warming in the shallow permafrost; and,
- The embankment section should be as thin as possible, or incorporate light-weight fill (e.g. blocks of expanded polystyrene) to reduce surface loading and thereby minimize the potential magnitude of settlements associated with creep in the underlying permafrost.

Additionally, thermal evaluations should consider the possibility of future climate warming. For example, Scher (2002) reported mean air thaw and freeze indices at Kotzebue (based on daily records from 1971 to 2000) of 2,110 and 5,704 °F-Days, respectively. However, based on general warming trends in mean monthly temperatures recorded[6] over the past 50-plus years at Kotzebue and Nome, the mean thaw index for the next 25 to 50 years could be projected to increase roughly 10 to 15 percent, while the freeze index may decrease roughly 15 to 25 percent.

4.3 Schematic Embankment Sections

In relative terms, we consider that the foundation soils at a new airport located in Alternate Area 1 would be more stable versus sites in either of the other two areas: e.g. the magnitude of potential thaw and consolidation settlements is likely lowest in Area 1; the settlements would likely be more uniform in Area 1, and there could be less potential for lateral spreading or significant slope failures in the embankments in Area 1. Alternatively, we consider there is

[6] http://climate.gi.alaska.edu/Climate/Location/West/

greater potential for massive ice formations and variable permafrost (i.e. abrupt or dramatic changes in the depth to permafrost) in Areas 2 and 3; and more variable terrain (i.e. abrupt and dramatic changes in fill thickness) in Area 2. Based on these preliminary conceptions, we suggest preliminary estimates of quantities required to form the new airport embankments (excluding the access road from Kotzebue) assume:

- Area 1 - The embankment should be at least eight feet thick; about 50 percent of the embankment will require insulation to mitigate the rate of thermal disturbance; and about 25 percent of the in-situ materials recovered from cuts would be reusable as fill, at least in the safety areas and aviation support areas.
- Area 2 - The embankment should be at least 10 to 12 feet thick; all embankment comprised of less than 12 feet of fill will require insulation to mitigate the rate of thermal disturbance; and none of the in-situ materials recovered from cuts would be suitable for reuse as fill, at least prior to it being thawed and drained.
- Area 3 - The embankment should be at least 10 to 12 feet thick; all embankment comprised of less than 12 feet of fill and situated over shallow permafrost will require insulation to mitigate the rate of thermal disturbance; embankment formed over thermokarst lakes (i.e. presumed very deep permafrost) should be surcharged for at least six to 12 months, to accelerate consolidation settlements in the foundation soils, prior to constructing the pavement structure; and none of the in-situ materials recovered from cuts would be suitable for reuse as fill, at least prior to it being thawed and drained.

4.4 Conceptual Pavement Structure

Guesstimating the total aircraft using the new airport would be equivalent to about 1,500 to 2,500 annual departures of a Boeing 737 (i.e. 160,000 pounds maximum takeoff weight), the pavement structure in critical areas should be comprised of at least four inches hot-mix asphalt concrete (HMA), over 18 inches asphalt-stabilized base course, over compacted and stable subgrade. Note that the thickness of HMA could be reduced to three inches in non-critical areas, but not the thickness of stabilized base course.

4.5 Material Source Issues

At present, we are not aware of any known or presumed material source on the Upper Baldwin Peninsula which singularly could produce the quantity of suitable borrow (i.e. coarse-grained as described in Section 4.2, above) assumed necessary to support construction of a new airport; with the possible exception of the bluff along the northeast side of the peninsula (see Section 3.1, above). Further, we are not aware of any known or presumed source of rock on the Upper Peninsula. However, there a number of existing or potential material sites in the Kotzebue Sound region, including the Baldwin Peninsula, which in combination could likely produce the required quantities of borrow, aggregate and stone; subject to further investigation to delineate the types of materials and reserves actually present at each.

Therefore, we recommend that further conceptual planning consider the following assumptions; at least until such time as the specific airport site(s) and actual material needs have been determined, and potential material sites have been investigated:

- Several material sources within the Kotzebue Sound region will have to be developed to provide the borrow, aggregate and stone necessary to construct the new airport;
- The movement of much, if not all coarse-grained borrow, aggregate and stone between the material source(s) and airport site will involve some transport by barge (Figure 16); and,
- Development of any material source will require significant infrastructure, include access roads and barge loading and unloading facilities.

Finally, barging costs are expected to vary significantly depending on the conditions in the loading and offloading areas (i.e. water depth and topography). Further, the coastal waters and near shore rivers around much of coastal Kotzebue Sound are very shallow, which will limit the size of barges and payloads, and/or require intermediate lightering.

FIGURE 16: BARGING MATERIAL TO KOTZEBUE
(From Nimiuk Point; 30 August 2006)

4.6 Future Geotechnical Investigations

Further study of the feasibility of relocating the Kotzebue airport within the Upper Baldwin Peninsula should include reconnaissance explorations at specific airport and material source sites (in particular along the northeast coast of the peninsula), including: aerial-photography interpretation; topographic and bathymetric mapping; test borings supplemented with geophysical surveys to characterize the foundation and material conditions (e.g. soils, ground ice and temperature), and laboratory testing to characterize the general soil index and physical properties.

5.0 CLOSURE

The discussions of site and material conditions, interpretations, and preliminary considerations presented in this document have been based on the pertinent development information listed herein. Significant alteration of any of these concepts could substantially affect the foregoing engineering interpretations and discussion. Additionally, because of the incomplete nature and coverage of the existing data collected during this phase of the program the possibility exists that subsurface conditions, important and/or significantly different from those described herein, may be revealed during further phases of this project.

R&M Consultants, Inc. performed this work in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No warranty, express or implied, beyond exercise of reasonable care and professional diligence, is made. This document is intended for use only in accordance with the purposes of study described within.

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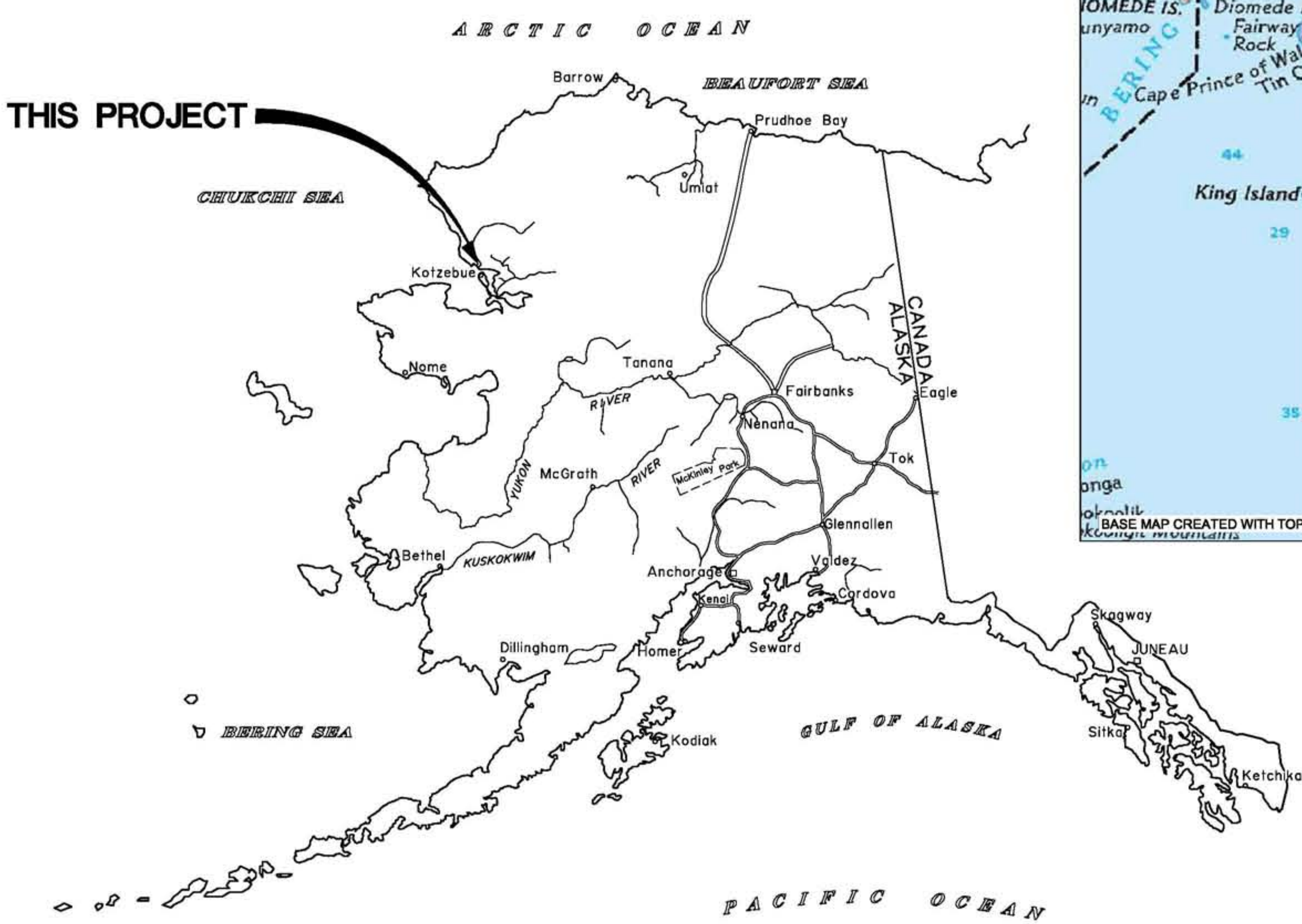
DRAWINGS



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STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

KOTZEBUE AIRPORT RELOCATION
FEASIBILITY STUDY

VICINITY MAP

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AS SHOWN	PKH	PKH	A-01
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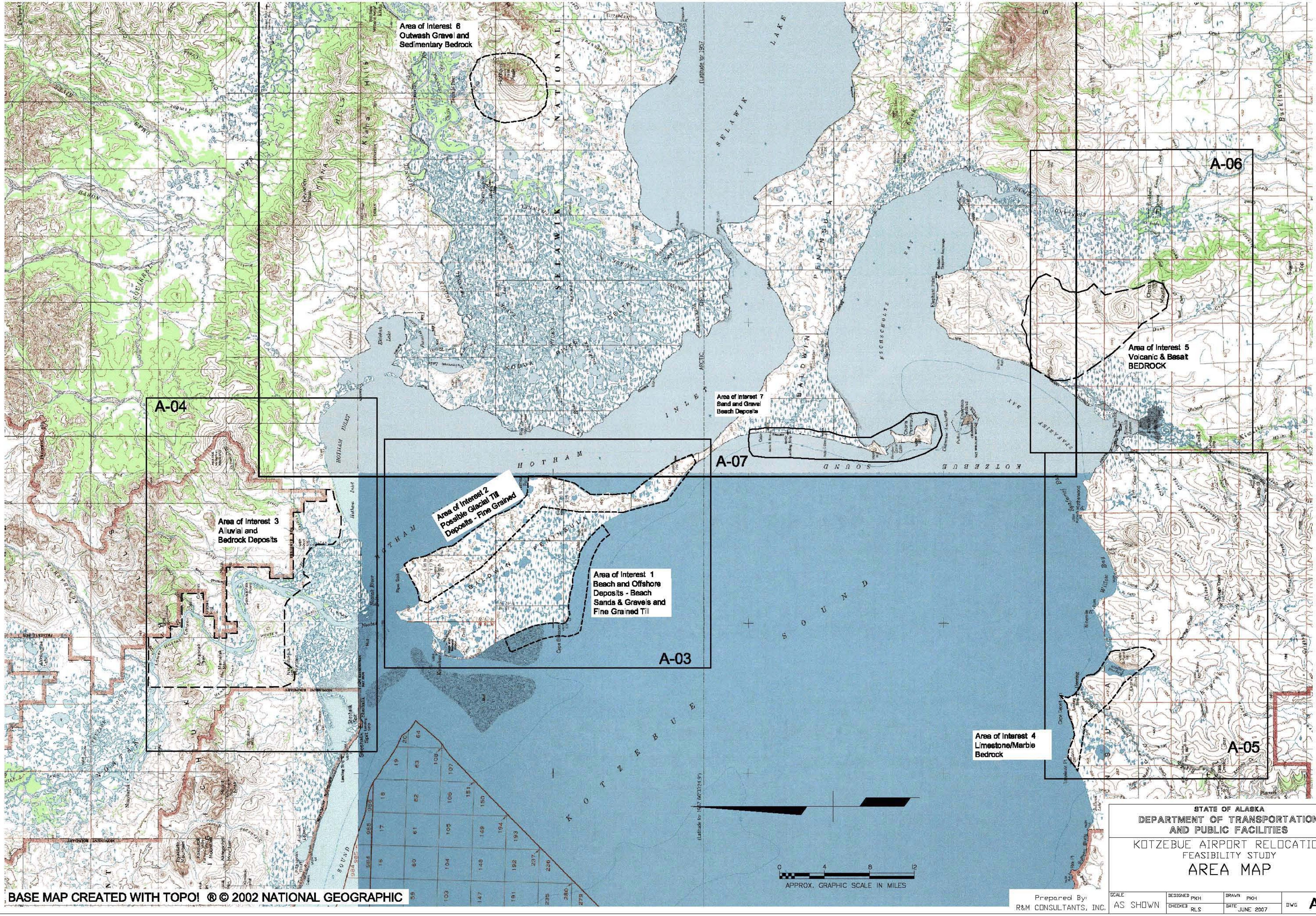

BASE MAP CREATED WITH TOPO! ® © 2002 NATIONAL GEOGRAPHIC

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APPROX. GRAPHIC SCALE IN MILES

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R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

KOTZEBUE AIRPORT RELOCATION
FEASIBILITY STUDY
AREA MAP

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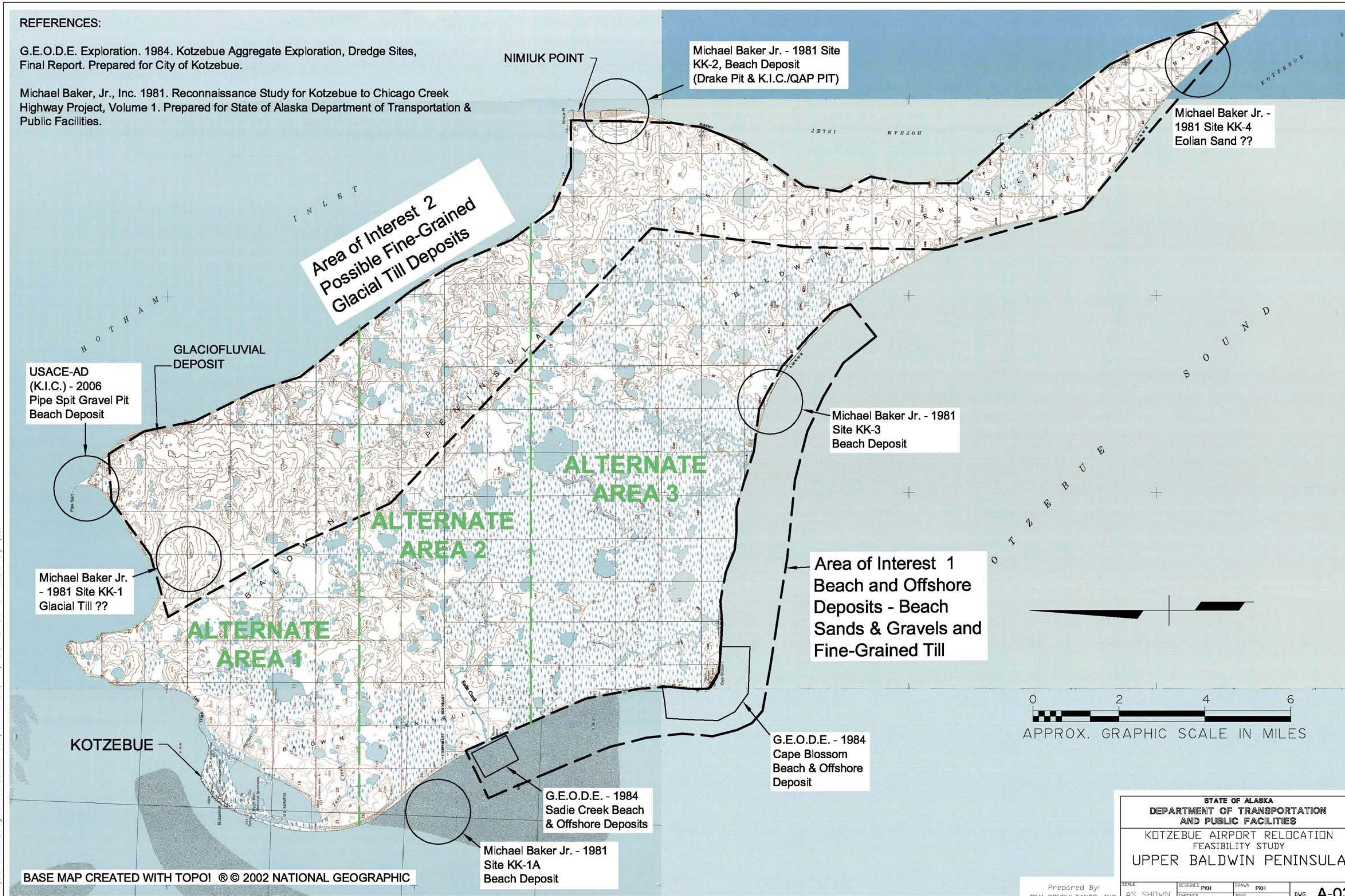

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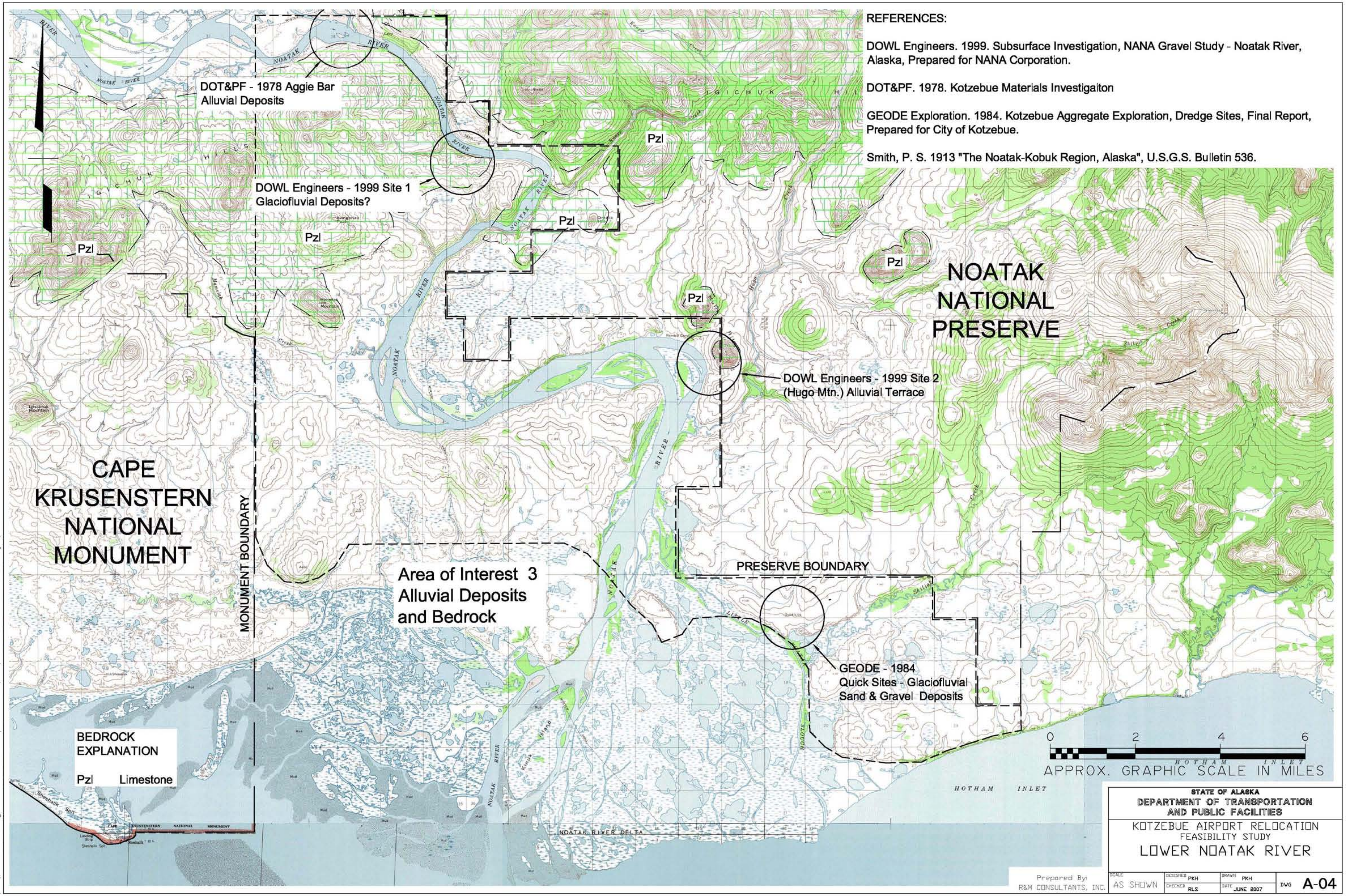

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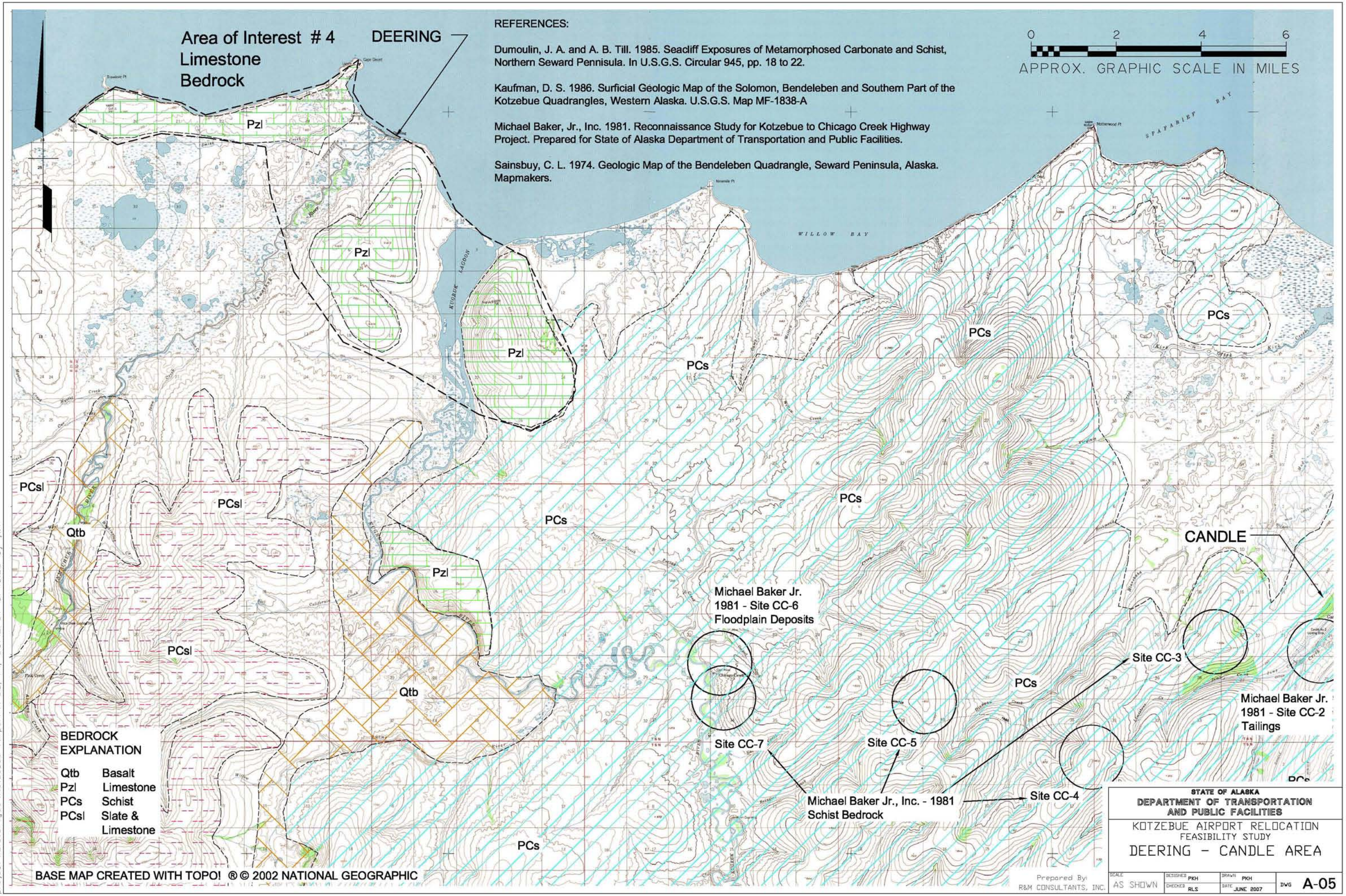

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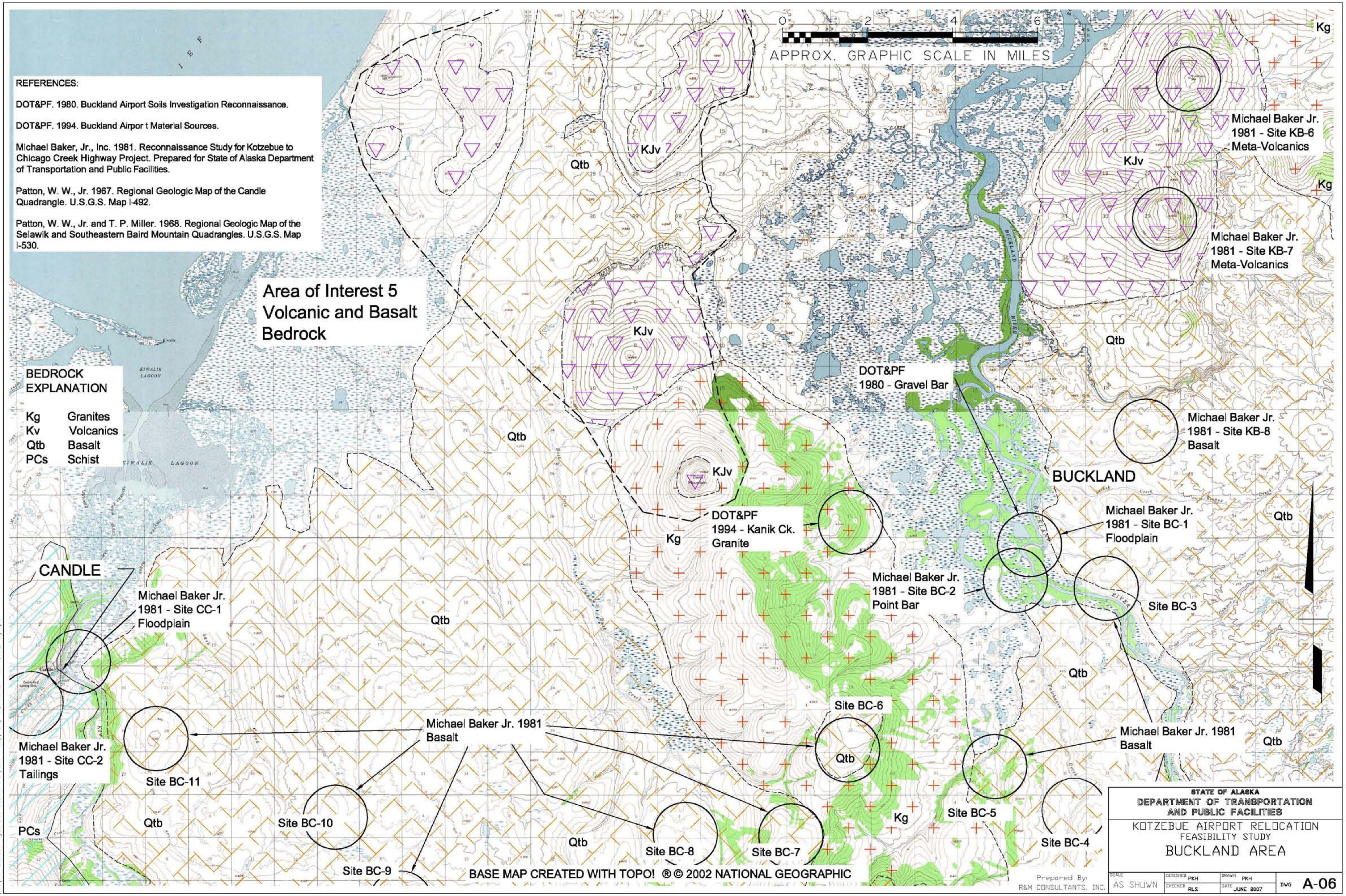

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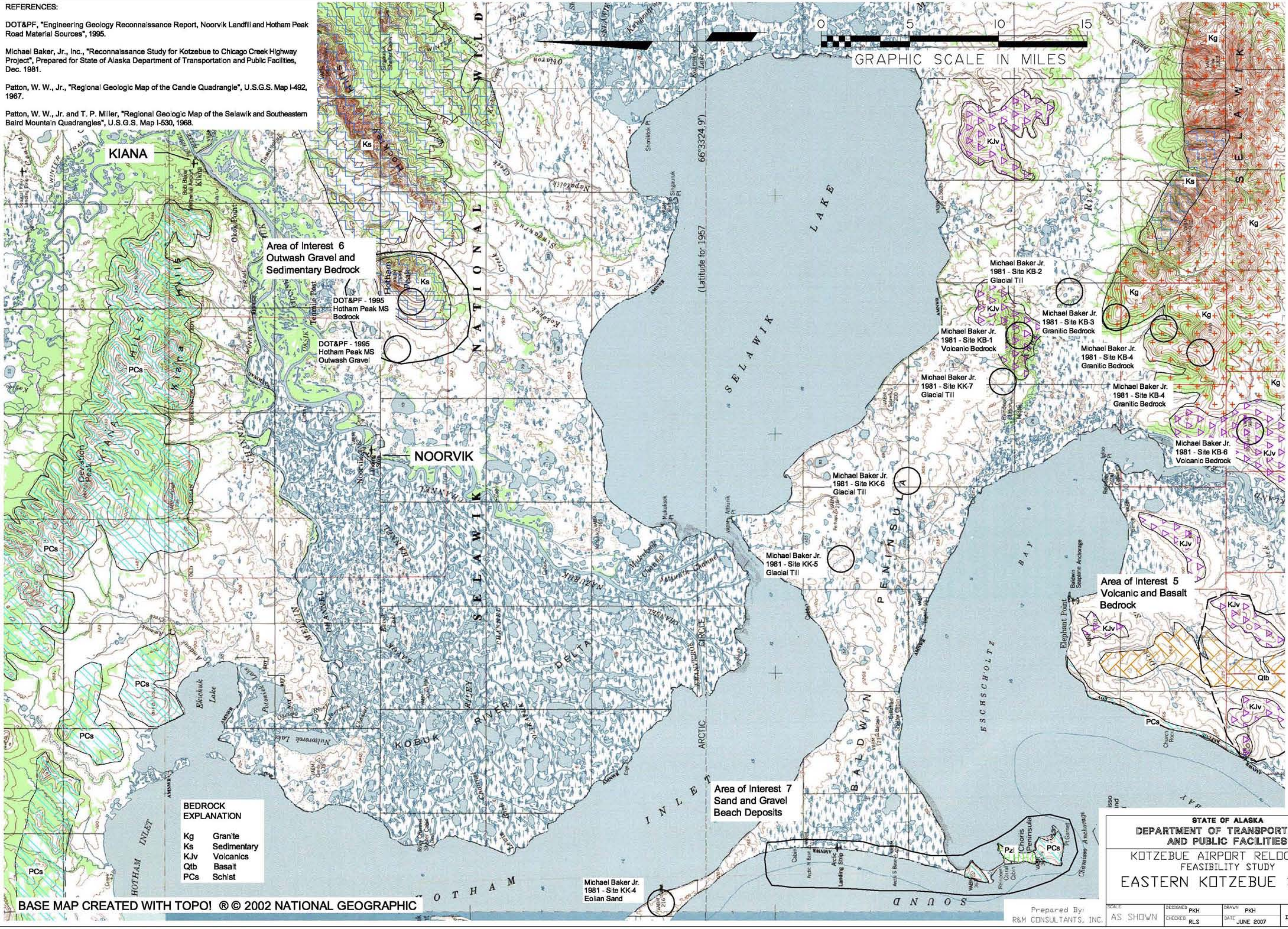

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

KOTZEBUE AIRPORT RELOCATION
FEASIBILITY STUDY

EASTERN KOTZEBUE SOUND

SCALE	DESIGNED PKH	DRAWN PKH	DWG A-07
AS SHOWN	CHECKED RLS	DATE JUNE 2007	

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