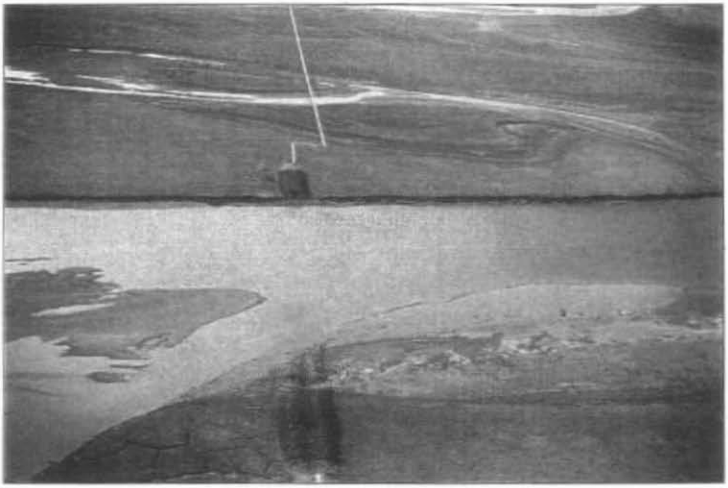
# REPEAT PHOTOGRAPHY OF BADAMI PIPELINE RIVER CROSSINGS: 1999 PROGRESS REPORT



TO:
BP EXPLORATION (ALASKA), INC.
ANCHORAGE, ALASKA

FROM:
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12 JANUARY 2000

# INTRODUCTION

The Badami pipeline was constructed with the best available technology to minimize environmental impacts to the arctic tundra. The elevated pipeline was built in the winter of 1997-98 from an ice road. Following construction, debris was cleaned from the route, leaving it as near to the undisturbed conditions as possible. The line was buried at the three rivers it crossed: Shaviovik, Kadleroshilik, and east channel of the Sagavanirktok. Between the river edges and where the pipeline emerged, the trench was backfilled with gravel and capped with tundra soil, except for the east end of the Kadleroshilik crossing, which consisted entirely of gravel. Backfill was heaped above the surface approximately 4-5 ft to compensate for settling in the trench. These backfilled trenches varied in length from about 100 ft on the east end of the Sagavanirktok crossing to 250 ft for the east end of the Kadleroshilik crossing. These crossings were considered environmentally important, and potential areas for erosion. Prior to construction, a plan to monitor conditions at river crossings was devised, using repeat photography (Hart and Laycock, 1996).

In August 1997, photopoints were installed at the three rivers crossed by the pipeline. Repeat photography was performed in 1998 and 1999. This is probably the first time that technique had been intentionally implemented to document 'before' and 'after' aspects of a construction project on the North Slope of Alaska. Repeat photography has been used successfully for recording vegetation aspect changes for many years. The images are easily interpreted, and are especially helpful to individuals unaccustomed to dealing with numerical plant data comparisons. Often copies of historical photos taken for other purposes have often been used as the 'before' images (Hart and Laycock, 1996). As the value of the technique became apparent, lay people, scientists, plant ecologists, foresters, range managers, etc. began using repeat photography to record changes over time on sites of particular interest. This report contains some of the image sequences acquired at Badami pipeline river crossings, in addition to several views to illustrate vegetation and conditions along the route.

# OBJECTIVE

The objective was to obtain a series of photographs through time of various views at the Badami Pipeline river crossings to document changes resulting from construction of the pipeline and the eventual vegetation. The series was designed to span the pre-construction through operational phases.

# APPROACH

Precise repositioning of the camera and an accurate record of when photos were taken are the critical underpinnings for this technique. To accurately reposition the camera, photopoints must be adequately marked to be readily relocated in the field. The original images for this project were to be rephotographed at least annually for the first years of pipeline operation. Without knowing pre-construction what environmental events would occur at these river crossings as a result of construction and operation of the pipeline, several general views at each location were obtained in anticipation that at least some of them would capture significant changes and prove useful.

# METHODS

To be effective, repeat photos must be composed as closely as possible to the original view. This requires repositioning the camera accurately, using the same camera size and identical focal length lens. Camera points (photopoints) were located and marked with aluminum capped rebar in August 1997, before the Badami Pipeline construction. GPS readings were recorded at these locations to assist future relocating. All frames exposed were recorded in a notebook (camera book), to provide necessary information to properly label the resulting images. A single lens reflex 35 mm camera equipped with a 50 mm (normal) lens was used. The camera was placed on a tripod positioned over each camera point. Minimum aperture was used to provide maximum depth of field in the resulting images. After the film was processed, the transparencies were labeled. Photos obtained in 1997 were taken to the field to guide in repositioning the camera for 1998 and 1999 photography. The 1997 and 1998 images have already been archived in the BP Exploration (Alaska), Inc. files at Anchorage.

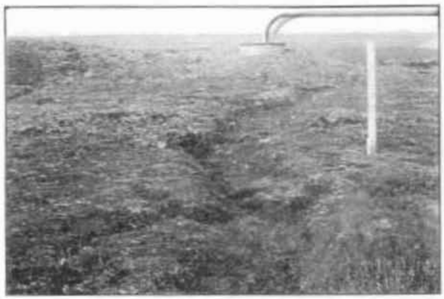
## RESULTS AND DISCUSSION

Weather was a major obstacle at the beginning of the project, in 1997. Wind blew rain on the lens, blurring portions of some initial images at the west end of the Sagavanirktok River crossing. There were survey stakes in the field, but I had no drawings showing what was to be constructed or where it was to be done, making it difficult to anticipate the most effective views to photograph. In spite of these limitations, we acquired useful image sequences that document aspect changes through time. These sequences at the river crossings consist of a mixture of subjects, some showing gravel fill, others showing the elevated pipeline. Changes resulting from construction have been recorded at each of the river crossings in these photo sequences.

### *Shaviovik River crossing*

Figure 1 shows the riser pipe at the east end of the Shaviovik River crossing. The soils at this site are well-drained, and polygon troughs are well-developed, indicating subsurface ice masses. Vegetation at this location is a mixture of grasses, sedges and forbs. Legumes and other showy flowering forbs are common, which is typical for well-drained habitats along rivers in this region. Through 1999, there was no evidence that construction activities caused thermokarst adjacent to the pipeline. However, the cover photo on this report (taken in August 1999) shows marked settling of that backfilled trench. Settling was not apparent in 1998 and must have occurred after our inspection. Since it is likely more settling will occur, delaying revegetation activities until the backfill becomes stabilized is probably the best action at this time.

*15 August 1997*



*14 August 1998*

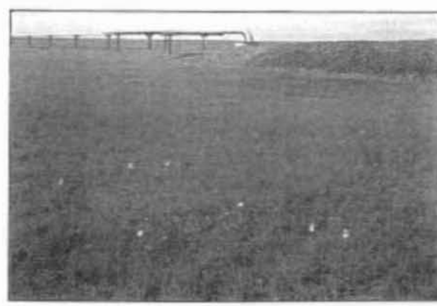
*27 August 1999*

*Figure 1. Northward view from photopoint (N70°08′41.7″; W147°15′13.1″) south of Badami pipeline at the east end of the Shaviovik river crossing. Upper, middle, and lower views were taken, respectively, on 15 August 1997 (pre-construction), 14 August 1998 (6 months following construction), and 27 August 1999 (18 months after construction). The photo sequence shows no significant changes in either the adjacent landscape soil and vegetation as a result of pipeline construction and operation. This is helpful information, because there were indications suggesting the site might have been prone to thermokarst.*

The west end of the Shaviovik river crossing is moist sedge meadow, formed in the flood plain of an old river meander. The habitat is more moist than habitat on the east side of the river, and polygon troughs are less prominent, suggesting the surface is geomorphically younger than on the east. Figure 2 photo sequence shows the pre-construction and post-construction view of portions of the elevated and buried pipeline and the riser pipe between the two. Following construction there was a little soil left on the surface next to the backfilled trench. Vegetation was not affected by that soil, and shoots produced in 1998 and 1999 emerged through the thin layer of soil. There is no evidence of thermokarst due to excavation and backfilling the trench. It is instructive to observe there was little settling of the backfilled trench at this end of the river crossing, in contrast to that on the east end (cover photo). That indicates less ground ice on the west side of the river and is consistent with observations of poorly developed polygon troughs on the west side of the river.

*15 August 1997*

*14 August 1998*



*27 August 1999*

*Figure 2. Northwest view from photopoint (N70° 08' 44.6"; W147° 15' 32.6") on south side of Badami pipeline at the west end of the Shaviovik river crossing. The upper, middle and lower photos were taken, respectively, 15 August 1997 (pre-construction), 14 August 1998 (6 months post-construction), and 27 August 1999 (18 months post-construction). The sequence shows no significant alterations in either the terrain or vegetation beyond that disturbed during trenching and backfilling.*

## Kadleroshilik River crossing

The Kadleroshilik River is the smallest of the three rivers crossed by the Badami Pipeline. During the summer, it can be waded just south (upstream) of the crossing. In 1998 and 1999 crews were able to safely wade the river at this location. During winter construction, it was difficult to determine the location of the river edge and impossible to acquire silty overburden to cover gravel backfilled trench on the east side of the river; consequently, the backfilled trench at this location is the longest (over

300 ft) of any of the three river crossings and consists entirely of gravel absent a covering of silty soil. Builders cut a trench through the backfilled gravel where they expected the river edge to be. This was to facilitate water flow and prevent flooding that could affect the backfill between the riser pipe and the river. However, their cut was approximately 50 ft from the actual river edge. That resulted in an 'island' of gravel back fill between the river and the backfilled trench. That mound of gravel was still in place when last observed in August of 1999. In 1997, I was unable to determine what was to be done at this crossing by the construction crews. Lacking the appropriate information, I only established one photopoint, hoping it would prove useful. Following construction, other photopoints were established (1998). All gravel fill at this crossing, including the 'island' between the river edge and backfill, was fertilized (300 lb/a 10-20-20) and seeded with a mixture of indigenous plant species on 31 July 1999 (McKendrick, 2000).

On the east side of the river, the landscape is a large gravel deposit that is geologically too young to have acquired a significant covering of silt. There is little accumulation of peat on the surface, which would improve the soil's water and nutrient supplying capacity for vegetation. As a result the vegetation is sparse and consists primarily of gravel colonizing plant species. Nitrogen fixing legumes and other forbs are common. However, wetland species which dominate most of the route and which are found at other river crossings were absent. It is likely there are no large accumulations of ice masses in the subsurface on the east end of this river crossing. Consequently, relatively little settling of this backfilled trench is expected. Figure 3 shows a sequence from 1998 and 1999 images of the gravel backfilled trench on the east end of the Kadleroshilik crossing, and there is little evidence of significant settling having occurred by August 1999, in contrast to backfill settling observed at the east end of the Shaviovik crossing.

*14 August 1998*

*27 August 1999*

*Figure 3. West to east view of backfilled trench at the east end (N70° 10' 39"; W147° 38' 13") of the Badami Pipeline crossing of the Kadleroshilik River. Upper photo was taken 14 August 1998, and the lower was taken 27 August 1999. This gravel fill was seeded with a mixture of indigenous plant species and fertilized with 300 lb/a (10-20-20) fertilizer on 31 July 1999 (McKendrick, 2000).*

Figure 4 shows an aerial oblique of the west end of the Kadleroshilik river crossing. The landscape is geomorphically older than on the east side of the river. There is a moderately thick accumulation of peat overlying silt atop a fluvial gravel deposit. Large low centered polygons are present, indicating presence of some subsurface ice masses in the vicinity. There was adequate peat and silt to cap the gravel backfill over the buried pipeline on this side of the river.

*Figure 4. Low angle aerial oblique view westward of west end of Badami Pipeline crossing of the Kadleroshilik River (27 August 1999). Peat and silt overburden used to cap the backfilled trench for the buried section of the pipeline appears dark, in contrast to the light-colored gravel fill around the riser pipe and for the helipad and check valve. Vegetation is moist rhizomatous sedge/Dryas meadow. In the distance, an old river terrace is apparent. Gravel fill at this location was seeded and fertilized 31 July 1999 (McKendrick, 2000).*

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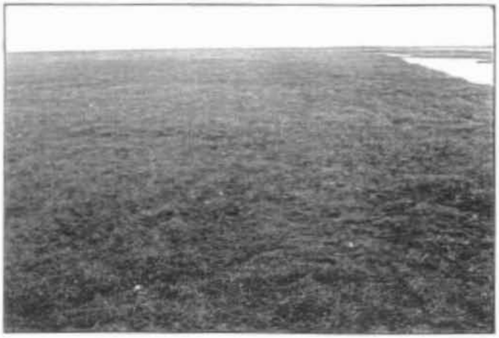
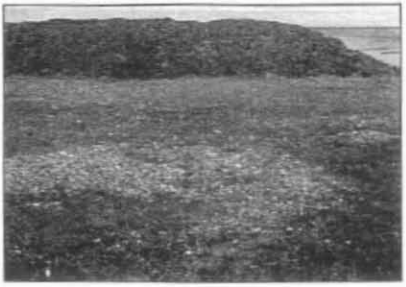
Figure 5 shows a sequence before and after construction at the west end of the Kadleroshilik River crossing. There was a thin scattering of gravel on a small area of the tundra surface beyond the boundaries of the trench. This appeared to have affected few plants. Vegetation was emerging through the gravel in 1998 and 1999, and in time it is expected the gravel will become less and less obvious. There has been no apparent settling of the backfill over the buried pipeline trench at this site, since construction. It is expected that eventually the gravel will be obscured by plant cover and accumulated litter.



*15 August 1997 - pre-construction*

14 August 1998



27 August 1999

*Figure 5. Northward view from south of the buried Badami Pipeline at the west bank of the Kadleroshilik River (N70° 10' 42.9"; W147° 38' 29.8"). This photo sequence consists of a pre-construction view (15 August 1997, on previous page), and two post construction views, (14 August 1998 and 27 August 1999, above left and right), respectively. The thin scattering of gravel deposited next to the pipeline during construction was less apparent 18 months after construction (1999), indicating vegetation was covering the stones.*

## *Sagavanirktok River crossing*

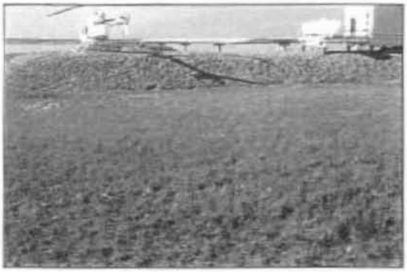
The east channel of the Sagavanirktok River is the largest stream crossed by the Badami Pipeline. The crossing is located in the river delta. The surrounding terrain consists of fluvial and aeolian deposits heavily dominated with sand-sized soil particles. The east end of the crossing occurs in a flat sandy area surrounded by stabilized dunes. Periodic flooding has deposited sand over the underlying gravel. Peat accumulations in the soil profile are several in number, thin and separated by layers of sand, indicating a long history of periodic flooding interspersed by stabile periods at this location. Sand was deposited when flooding was frequent. Peat formed during periods when flooding was rare. Vegetation consists of an ecologically young wet rhizomatous sedge meadow in the flats and sand-adapted grasses and forbs on the dunes. There is a conspicuous absence of moss on the soil surface, confirming the current river conditions regularly flood this site. Recent river erosion appears to have become increasingly active at this location. An abandoned fish camp just upstream of the crossing that was present prior to 1997 was completely removed during spring flooding in 1998. Based on my 1997 examination of the camp, I judged it to have been in use as recently as the 1950's, according to refuse at the site.

On the west bank, stream erosion was particularly noticeable between 1997 and 1999. This erosion was unrelated to the cutting away of backfill over the buried pipeline, discussed later, and it is evident in Figure 9. In flat terrain, such as this river delta, channel erosion normally occurs predominantly on one side of a river channel at a time, and as the stream meanders, cutting and filling occur on opposite sides of the channel. Cutting simultaneously on both sides at this location suggests increased water flow. Perhaps increased flow has been induced by changes in the main channel upstream, which recently forced more water toward the east side of this braided river. Periodic fluctuation in river flow is consistent with the varied deposits of sand and peat in this area.

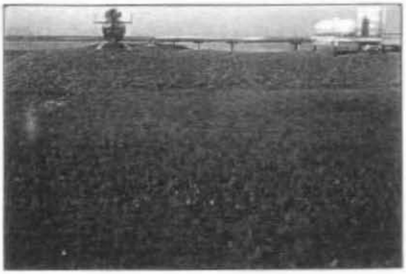
An access was cut into the river bank on the east side to get equipment into the river channel during construction. This was backfilled and capped with soil upon completion of the pipeline burial. At the east end of this access, subsidence and water has accumulated. It was suggested during one inspection with Alaska Department of Fish and Game personnel, that *Arctophila fulva* should be sprigged into this pool to improve its appearance. In July of 1998, that was done. However, the site needs fertilizer to improve conditions for the *Arctophila*. Because subsidence is still occurring, it would be best to allow more time for stabilization before more revegetation activities are undertaken in the small pond. An appropriate time to fertilize this pool would be when the gravel fill is seeded and fertilized at the east end of the Sagavanirktok crossing.

The photo sequence acquired on the east side of this river crossing indicate no damages to soil and vegetation beyond the boundaries of construction (Figure 6). If any gravel was spilled outside the helipad border, it was not apparent. The absence of polygon troughs indicates there are few ice lenses at this east end of the pipeline river crossing. Thermokarst is not anticipated at this location.

*15 August 1997*



*14 August 1998*



*27 August 1999*

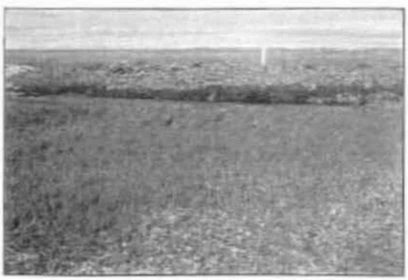
*Figure 6. Photo sequence is a westward view of the Badami Pipeline crossing on the east side of the east channel of the Sagavanirktok River (N70° 13' 28.9"; W147° 56' 42.3"). The helipad and gravel fill for a check valve station were constructed on the area included in this view. Upper, left lower and right lower photos were taken, respectively, on 15 August 1997 (pre-construction), 14 August 1998 (post-construction), and 27 August 1999.*

Unlike the other river crossings, the west end of the Sagavanirktok crossing developed an erosion problem. The pipeline was constructed through a naturally-occurring drainage. Once subsidence in the backfill over the buried pipe began, water soon filled the depression and softened the soil. At breakup, the head of water cut through the backfill, washing much of it into the river and formed a channel (gully) through the pipeline trench. Headward erosion of this channel was controlled by the natural vegetation of rhizomatous sedges up slope from the pipeline trench. Gully depth within the pipeline trench was controlled by the water elevation in the river. Hence, deeper erosion within the pipeline trench is unlikely, without major lowering of the sea level. That and the depth to which the pipeline was buried prevented any damage to the pipeline integrity from this erosion process. The major environmental consequence presented by all this is increasing the risk for draining the water body up slope (see upper photo Figure 9). That pond was formed in the depression of an abandoned river channel. It is considered by wildlife biologists as valuable habitat for waterfowl, because it contains an extensive bed of *Arctophila fulva* Based on observing stickleback fish in the shallow margins of this pond in 1998, I would expect it to also be a feeding area for loons.

Some people may find the erosion aesthetically objectionable, until it becomes vegetated. That could be an additional reason for revegetating the gully. However, treatment of the site to control erosion is unclear at this time, and that must be completed before any revegetation plan is devised.

Figure 7 is a photo sequence that captured the development of the erosion at the west end of the Sagavanirktok crossing. Examining the 1997 photo shows a strand of red grass (*Arctophila fulva*) in the midst of a dark green wet sedge meadow. This indicated the presence of a waterway which drained the pond up slope. Within that waterway, ponding against the backfill and marked subsidence in the backfilled trench was evident in the 1998 photo. In the 1999 photo, much of the backfill has been removed. Signs of the potential problem were present prior to construction, but they were not adequately recognized. Perhaps experiences gained here will be helpful in siting future pipeline projects in the region. The photo sequences in Figures 8, 9 and 10 also show the backfilled trench before and after erosion occurred. Figure 11 is a view of the gully from the river toward the riser pipe.

*15 August 1997*



*14 August 1998*

*27 August 1999*

*Figure 7. A photo sequence of the Badami Pipeline crossing on the west side of the east channel of the Sagavanirktok River (N70° 13' 34.4"; W147° 58' 19.5"). Upper, lower left and lower right photos were obtained, respectively, on 15 August 1997 (pre-construction), 14 August 1998 (post-construction), and 27 August 1999. View is northward across the area transected by the buried pipeline.*


*Figure 8. Northeastward from photopoint #2 at the west end of the Sagavanirktok river crossing. Left image shows backfill over the buried pipeline 14 August 1998, and the right view shows the same area on 27 August 1999 after water removed most of the backfill.*

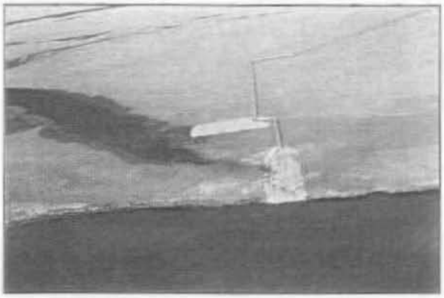
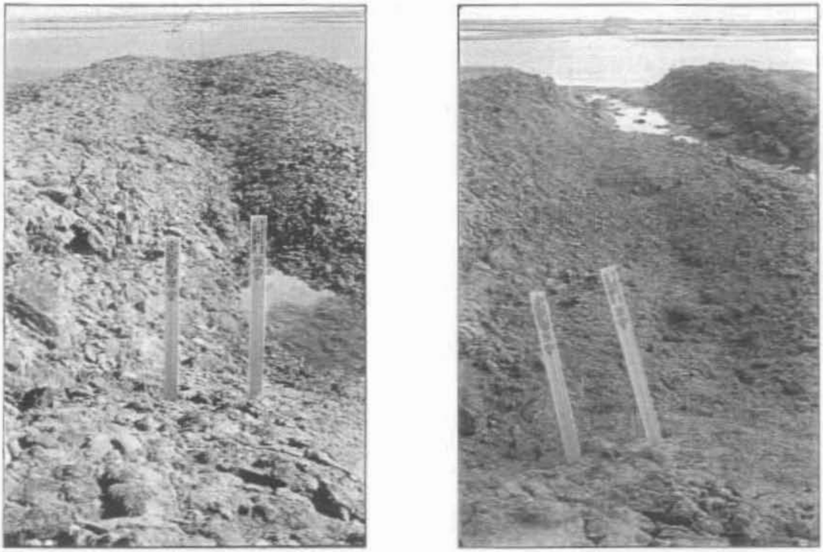



*Figure 9. Aerial oblique views of Badami Pipeline on the west side of the Sagavanirktok crossing 22 July 1998 (upper) and 27 August 1999 (lower). Two sets of crawler tracks are prominent in the tundra to the left of the backfilled trench. A single faint set of tracks can be seen to the right of the pipeline above the helipad (upper photo). These marks are believed to have resulted from heavy equipment moving across the tundra during construction without protection from the ice pad. They may not cause thermokarst and will probably become vegetated naturally in time. Those in the margins of the Arctophila fulva bed are apt to persist as depressions in the soil for an indefinite period. Vegetation cover will obscure them more quickly in the wet habitats than on the dry sites. This type of tundra marking is relatively uncommon for the Badami Pipeline, and is pointed out here, because it appeared so obviously in these photos. Also important to note is the marked erosion and calving of the river bank that occurred between the 1998 and 1999 photos.*



*14 August 1998* *27 August 1999*

*Figure 10. View eastward of backfilled trench over buried pipeline on the west side of the Sagavanirktok River. Photos were obtained, respectively on 14 August 1998 (left) and 27 August 1999 (right). Water was impounded in a subsidence over the pipeline in 1998, and had cut through the backfill during spring breakup in 1999. The east end of the river crossing can be seen in the distance.*

*Figure 11. View westward up the gully cut through the backfill over the buried pipeline at the west end of the Sagavanirktok crossing for the Badami Pipeline (27 August 1999).*

# Conclusions and Recommendations

This monitoring of pipeline construction and operation is providing insight into the environmental aspects between terrain and vegetation and construction impacts. If adequately documented, it should be useful in future permit applications for the region. It was most instructive at the west end of the Sagavanirktok river crossing, where erosion of the backfilled trench occurred. Continued monitoring of the backfill heaps will be useful not only in recording vegetation recolonization, but also to document the fate of these mounds. Will they remain as they are, or subside to more nearly match the surrounding terrain? What types of indigenous plants will colonize? We already know they are preferred habitat by ground squirrels, according to our 1998 observations. Also important to this method of crossing rivers with pipelines is the rate of bank erosion in the region. Prior to this project the subject was quite speculative. Now there are markers and known dates that will provide firm reference points for future observations.

Natural erosion seemed to accelerate at the Sagavanirktok River during the 1997-99 period. It would be wise to remain alert to that. It poses little immediate threat to the buried pipe, but should the river channel erosion continue at an accelerated rate, it may eventually reach the risers on either side of the river. That would necessitate reconstruction of these setbacks. Setbacks for the east and west ends of the Sagavanirktok crossing are now approximately 100 and 120 ft, respectively.

Settling of the backfill has been relatively minimal at most locations. There were two exceptions, the east side of the Shaviovik and west side of the Sagavanirktok crossings. When it appears that further settlement is unlikely, it may be necessary to smooth the backfill to fill in depressions and cut off high spots. Revegetation of the soil should be delayed until it is certain subsidence will no longer occur to a large extent. Gravel fill will require seed and fertilizer applications to establish vegetation, because the natural process will be very slow for various reasons. Artificial revegetation involving indigenous plants adapted to gravel substrate is the preferred approach. This has already begun with the seeding and fertilizing of gravel fill at the Kadleroshilik river crossing in July 1999 (McKendrick, 2000). Seeding gravel fill for helipads and check valves can proceed as time and materials permit.

Natural revegetation is the preferred approach for soil-covered backfill, in the absence of need for erosion control. Natural recolonization will provide a plant cover best adapted to the habitat and concordant with the indigenous flora and fauna. That will disarm potential opposition to development in the Arctic because it might lead to altering tundra vegetation with exotic plant introductions. Natural vegetation recolonization on soil-covered backfill is beginning slowly and has occurred primarily from a few vegetative plant parts surviving in the soil. Owing to changes in site hydrology, it is unlikely that many of the original plant species will find these backfill mounds suitable. Consequently, species from adjacent better drained sites will eventually occupy these habitats. Getting the seed from the source to the target will be the factor controlling how quickly or slowly this occurs. Plants whose seeds are naturally airborne will move in most quickly. Species producing seeds that are not easily carried by wind will be the slowest to invade. Natural seedling establishment is expected to occur in time. It can be accelerated by collecting seed from appropriate species and spreading those seeds on the backfill mounds. For most locations, aggressively assisted revegetation will not be necessary, and heavy applications of fertilizer and exotic grass seed on mineral soils would most likely compete with and delay indigenous plant establishment.

The west end of the Sagavanirktok crossing is a separate matter. Presumably some type of repairs for erosion control will be installed at that site, and depending upon the nature of those features, assisted revegetation may be needed to stabilize the soil.

The photo records begun with this project should be continued to document trends in vegetation recovery and record effectiveness of construction techniques on protecting the habitat. This will prove valuable for evaluating erosion controls, which are expected to be implemented at the west end of the Sagavanirktok river crossing, disappearance of vehicle marks on the tundra, rate of natural revegetation, and effectiveness of assisted gravel revegetation.

## ACKNOWLEDGEMENTS

In 1997, Ericka Herlugson assisted with installing photopoints and recording GPS data. Daniel McKendrick and Conce Rock assisted with the photography in 1998 and 1999, respectively. Peg Banks edited and formatted the final version of this report. BP Exploration (Alaska), Inc. requested and funded the project.

## LITERATURE CITATIONS

Hart, R.H. and W.A. Laycock. 1996. Repeat photography on range and forest lands in the western United States. J. Range Management 49:60-67.

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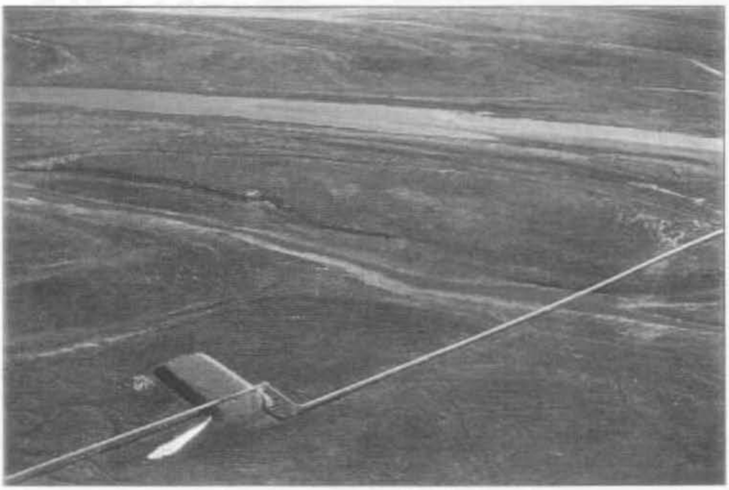

*Back cover: Southwest to northeast aerial oblique view of check valve and helipad for Badami Pipeline just west of Shaviovik River crossing. Construction is 16 months old in this 23 June 1999 view, and few marks appear in the tundra from construction. Exceptions are vehicle tracks beyond protection of the ice pad used for building the pipeline.*