A Systematic but Not-Too-Complicated Approach to Cumulative Effects Assessment[1]

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In 1994, Ray Clark focused attention on the potential of cumulative effects assessment (CEA) to serve as a predictive tool for gauging the sustainability of proposed development projects (Clark 1994). At that time, CEA was in the early stages of its maturation in the United States. Although the 1978 CEQ regulations (40 CFR 1500-1508.7) required National Environmental Policy Act (NEPA) practitioners to consider not only the direct and indirect environmental effects of a proposed action and each of its alternatives, but also the potential cumulative effects, the brief cumulative effects sections that appeared in most environmental assessments (EAs) and environmental impact statements (EISs) in the United States were usually non-specific and conjectural—and sometimes absent. (For a critique of CEA practice at that time, see Burris and Canter 1997.) The situation improved somewhat after January 1997, when the President's Council on Environmental Quality (CEQ) issued its handbook *Considering Cumulative Effects under the National Environmental Policy Act* (CEQ 1997), the first official guidance in the United States on how to perform cumulative effects assessments. (For a pre- and post-1997 time-comparison analysis of CEA practice, see McLaughlin 2001.) Now, in 2002, CEA practice is farther along the maturation path, and we can turn again to Clark's idea of applying CEA as a tool for sustainable development.

In Alaska, the question of sustainability is foremost in the minds of federal, state, and borough resource agency representatives, because decisions regarding development projects are made in the context of an environment of unspoiled wilderness or near-wilderness, intact and healthy fish and wildlife populations and habitats, and unparalleled beauty. But these conditions are relative: the outside world is intruding, with its pressures for development and tourism, and there is risk associated with every authorization and permit that the decision will add its increment to accelerating change. Under these circumstances, there is a growing interest in CEA, and the focus—whether explicit or implicit—is on sustainable development. Currently, for example, there are two major federal efforts underway to assess the cumulative effects of petroleum development in Alaska. The U.S. Environmental Protection Agency (EPA) is sponsoring a comprehensive study by the National Research Council on the cumulative environmental effects of Alaskan North Slope oil and gas activities, and the U.S. Department of the Interior, Bureau of Land Management is examining the cumulative effects of the Trans-Alaska Pipeline System (TAPS) as part of the EIS required to reauthorize the TAPS right-of-way. The attention being given to CEA and sustainability by regulatory agencies is reflected in the private sector, because Alaskan development projects proceed under intense regulatory scrutiny, and the petroleum, mining, timber, and commercial fishing industries, in particular, not only stay in close step with regulatory trends, but have legitimate interests of their own in promoting sustainability.

In our experience as practitioners, the biggest obstacle facing the public and private sectors alike in conducting CEA is the lack of a straightforward approach that can be applied inexpensively, quickly, and consistently in compliance with the CEQ handbook. Other, less tractable obstacles stand in the way of assessing sustainability in a broad and coordinated way across different agencies, institutions, and planning bodies. In this paper, we describe an approach we are finding useful in facilitating a consistent procedure for CEA, and we close with a few thoughts on pursuing Clark's vision of using CEA as a tool not only for assessing potential sustainability, but for guiding development in that direction as part of an open and public process.

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[1] Paper presented at the 22nd Annual Conference of the International Association for Impact Assessment, The Hague, June 15-21, 2002.
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Approach

Since 1999, we have been developing an approach to CEA that closely follows the CEQ handbook, incorporates subsequent guidance from the EPA Office of Federal Activities (1999), and provides a straightforward and consistent method that can allow diverse projects to be compared on common ground so that an integrated, collective, and continually evolving synoptic picture emerges. Variants of this approach have been applied to the TAPS right-of-way reauthorization process and to a major EIS now underway regarding the future management of commercial groundfish fisheries in the Eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and North Pacific Ocean. In addition, this approach has been developed to assist oil and gas industry staff and consultants in preparing CEAs for in-house environmental reports prior to the regulatory analysis of proposed oil and gas development projects on Alaska's North Slope. We want to emphasize, however, that the approach presented here has not been formally accepted by government agencies or by private industry and is not intended to replace or refute guidance by agencies involved with cumulative effects assessments. Although not as comprehensive as strategic environmental assessment (SEA) procedures, the CEA approach described here may have useful application not only in the United States, but also in other nations where NEPA-like requirements are in effect or being developed.

This approach has five parts, in the following sequence:

A. Scoping: Identify Issues, Resource Components, and Boundaries;
B. Organizing: Describe the Affected Environment, Predicted Direct and Indirect Effects, and External Influences;
C. Screening: Identify Potential Cumulative Effects;
D. Evaluating: Determine Significance and Whether Beneficial or Adverse; and
E. Mitigating, Monitoring and Adaptive Management

Each of these parts consists of one or more steps (11 total) that correspond to and comply with the 11 steps in the CEQ handbook, but occur in a slightly modified form and in a different order from the CEQ sequence to aid users in performing analyses as efficiently as they can (Table 1). At the same time, like the CEQ recommendations, the approach presented here is not a cookbook: it requires latitude and judgment on the part of the practitioner, and provides only the outer structure of the CEA process to facilitate consistency and comparability of results from one CEA to another. This feature is important for considerations of sustainability, as we discuss later in this paper. In addition, this approach, like the CEQ guidelines, does not address analytic methodology; this, especially, is up to the practitioner (see Canter 1996, 1997).

By following these recommendations, users develop a series of tables (CEA matrices) and supporting text. The CEA matrices identify and categorize cumulative effects potentially related to the proposed action and alternative actions, including the no-action alternative. Each cell of a matrix is referenced to supporting text that explains the rationale for the entry in the cell. This approach provides a level of transparency and accountability that facilitates public, agency, and stakeholder participation in, and review of, CEAs. In addition, the consistency of approach from one CEA to the next allows the comparison of predicted cumulative effects among different development proposals as well as the post-development comparison of predicted versus actual environmental effects among different projects. This aspect is conducive to database tracking and trend analysis over an extended period, an important consideration in using CEA as a predictive tool for sustainability assessment.

A. Scoping: Identify Issues, Resource Components, and Boundaries

1. Scoping process: At the start of the project, hold scoping meetings and interviews with stakeholders and concerned individuals (the general public; potentially affected local residents, businesspeople, and landowners; members of non-governmental organizations; agency representatives; and others). The early scoping meetings and agency coordination should cover not only information and opinions regarding potential direct and indirect (secondary) effects of the proposed action and its alternatives, but also issues and concerns that might be relevant to potential cumulative effects on the physical, biological, and social (cultural and socioeconomic) environments. This process should identify relevant past, current, and emerging issues of concern, including potential future actions, and seek to incorporate traditional knowledge. Each alternative, including no action, should be addressed as fully as the proposed action, not only during scoping but throughout the CEA.

2. Background research: Review pertinent environmental assessments, environmental impact statements, environmental study reports, the peer-reviewed literature, agency file data where available, and other sources to identify and characterize past, current, and reasonably foreseeable future actions other than the proposed action and its alternatives (i.e., external actions) that have affected or could affect the physical, biological, and social environments.[5] Do the same for natural events (seismic events, floods, severe winters, climate change, etc.). Use the scoping input from step 1 to guide the inquiry.

3. Resource components: Using the information gained from the scoping process (step 1) and background research (step 2), identify on a preliminary basis the relevant resource components (e.g., air quality, water quality, fish and wildlife species,[6] wetlands, income, employment, etc.) for the physical, biological, and social environments. It is helpful to arrange the resource components in a table or tables to support the analysis and supplement the text. The preliminary list of identified resource components can be refined as more information becomes available during the analysis.

4. Geographic scopes: Using the external human actions and natural events identified in step 2 and the resource components identified in step 3, define the appropriate geographic scopes for the physical, biological, and socioeconomic environments.[7] For CEAs, the geographic scopes will usually encompass (a) the location(s) of the alternatives, plus (b) the areas within which the physical, biological, or socioeconomic resource components might be affected directly or indirectly by any alternative, plus (c) the areas in which external human actions and natural events could interact with the direct and/or indirect effects of any alternative. Geographic scopes will usually be broader for cumulative effects than for direct and indirect effects, because external factors at greater distances from the site of the proposed action and its alternatives may be involved. Therefore, the broad geographic scopes established for the CEA may also incorporate the direct and indirect

[5] If the proposed action or alternatives are a continuation or new phase of an ongoing program, past and current actions in the same program should be included in this review, along with reasonably foreseeable future program components that are not directly part of the proposed action and its alternatives.

[6] To keep the analysis within manageable bounds, fish or wildlife species with similar life histories, geographic ranges, and population-limiting factors can be combined as a single resource component. For example, many waterfowl, shorebird, or small mammal species can be lumped in this way, *provided species-specific characteristics that make a difference to the analysis are identified and discussed in the text.* In other cases, a single species (e.g., polar bear, caribou, spectacled eider) may be justified as a separate resource component if it has special biological or management status (e.g., Threatened and Endangered species).

[7] The physical, biological, and socioeconomic environments may have different geographic scopes, depending on their respective resource components, or they may all share one comprehensive geographic scope. In either case, present the supporting rationale and then be consistent in usage throughout the CEA.

effects analyses, removing the need to define separate geographic scopes for direct, indirect, and cumulative effects.

5. Time scope: Establish a temporal scope for the CEA that covers the past, present, and reasonably foreseeable future. Following EPA guidance, the cumulative effects benchmark, here called the environmental reference point, should be a year in the past that represents the environment in its pre-development condition or, if sufficient information on the pre-development condition is lacking, a more recent year representing the environment in an ecologically sustainable condition (EPA 1999). Because the environmental reference point is set in the past, it is different from the baseline for direct and indirect effects, which is usually set in the present just before the planned start of the proposed action and its alternatives. The advantage of setting the CEA benchmark in the past is that it provides a starting point in time. Using this starting point, it will be possible to describe (to the extent available information allows) the sequence of human actions and natural events that occurred and interacted in the past, leaving residual cumulative effects that continue to influence present environmental conditions (the baseline). If the preponderance of evidence indicates that the present environmental condition is ecologically sustainable, the environmental reference point should still be placed far enough in the past to allow a description of past human actions and natural events that could be contributing to ongoing cumulative effects. The idea here is that the proposed action or its alternatives could add to and interact with cumulative effects that are already taking place as a result of past actions and events (EPA 1999).

With respect to the reasonably foreseeable future, the expiration of the enabling permit or license may be a logical cutoff point, but keep in mind that some effects of the proposed action and its alternatives may persist, and interact with the effects of external human actions and natural events, well beyond the planned project lifetime. As is the case with geographic scope, the time scope for the CEA will encompass the temporal scopes for the direct and indirect effects analyses, making it possible to use a single time scope for all three types of impact assessment. The boundaries or cutoff points for the backward-looking and forward-looking parts of the time scope can be adjusted as the analysis proceeds, and they may vary from one resource component to another.[8]

B. Organizing: Describe the Affected Environment, Predicted Direct and Indirect Effects, and External Influences

6. Affected Environment: Plan and prepare the Affected Environment chapter. The structure, method, and content of this chapter are essential components of the CEA. It is the place where past, present, and reasonably foreseeable future actions and events (from steps 1 and 2) are systematically organized and described in relation to the resource components and geographic and time scopes (from steps 3, 4, and 5). Begin by classifying and describing those resource components of the physical, biological, and social environments that are relevant to the direct, indirect, and cumulative effects assessments. Then, starting in the past at the environmental reference point (from step 5), summarize how the selected resource components have historically been shaped and altered by human actions and natural events through the period from the environmental reference point up to the baseline (the present-day benchmark used for assessing direct and indirect effects). Be sure to note residual effects from the past that continue to influence the baseline (present) conditions. These residual effects will be a crucial part of the CEA to be developed in the Environmental Consequences chapter. Next, summarize human actions (other than the proposed action and its alternatives) and natural events that presently influence the resource components or could affect them in the reasonably foreseeable future. Finally, prepare a concluding section that synthesizes the key points in the Affected Environment chapter and identifies

[8] For example, the future cutoff point for a particular species could be based on evidence regarding the time required to recover from stress relating to a population-limiting factor. In such cases, the recovery times, and therefore the future cutoff points, are likely to vary from one species to another (e.g., caribou versus northern lemming).

apparent environmental trends as indicated by past and ongoing changes in the resource components.[9] Wherever appropriate, use informative tables, maps, and diagrams to support and clarify the text.

7. Direct and indirect effects: After the Direct and Indirect Effects sections of the Environmental Consequences chapter have been completed, review the predicted direct and indirect effects of the proposed action and its alternatives on the resource components. Note which potential effects are evaluated as significant and the criteria used to make that determination, including the significance threshold. For each potential direct or indirect effect evaluated as significant, note also whether it is considered beneficial or adverse. (See text boxes, "Determining Significance" and "Beneficial or Adverse?")

8. Cumulative effects assessment (CEA) matrix: Working through one project alternative at a time, prepare a cumulative effects assessment matrix for each resource component (from step 3), listing each predicted direct and indirect effect of the alternative on that resource component in the left-hand column and whether the predicted effect has been evaluated as significant (S) or not significant (NS) (from step 7). A hypothetical example of a filled-out CEA matrix, with numbered step-by-step guidance, is shown in Tables 2a and 2b at the end of this paper.

9. External influences: For each CEA matrix, array the identified past, current, and reasonably foreseeable future external influences along the top as column headings. These are the human-controlled actions and natural events identified during the background research in step 2 and the historical analysis in step 6. Add two more columns on the right-hand side to characterize potential cumulative effects with respect to (1) whether they are predicted and (2) whether they are considered significant and, if so, beneficial or adverse. The matrix is now a tool that will help to organize and document the remainder of the analysis.

C. Screening: Identify Potential Cumulative Effects

10. Matrix cell completion: In each CEA matrix, enter the appropriate information for each cell in summary form. The cell should reference the corresponding section of the text that contains the full discussion and rationale supporting the cell content. For example, to summarize the predicted direct effect on sheet flow caused by a gravel access road that would be constructed through wetlands: "Access road will block sheet flow, causing ponding on the upstream side and drier conditions on the downstream side (Sec. 4.2.7)." In the columns for past, present, and reasonably foreseeable future external actions and natural events, summarize how each external influence might add to or interact with each listed direct or indirect effect of the alternative under consideration. Where no involvement by the external influence is foreseen, place *N/A* (for Not Applicable) in the cell.

When the appropriate information has been entered, it will be evident whether there is the potential for a cumulative effect to be associated with each predicted direct or indirect effect of the alternative under consideration. Therefore, in the "Potential Cumulative Effect?" column, briefly characterize each identified cumulative effect. For example, to summarize the potential cumulative effect of other gravel roads adding to sheet flow blockage caused by the alternative under consideration: "Access roads to Pads A, B, C, D, and E will further block sheet flow through wetlands, creating multiple impoundments within a 100-hectare area surrounding the proposed project location" (cite the corresponding text section). If no potential for a cumulative effect is identified, enter No in the appropriate cell of the "Cumulative Effect?" column. Finally, make sure that

[9] One of the principles set forth in the CEQ guidelines (CEQ 1997) states that "It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful." Therefore, provide a concise account of key external actions and events thought to influence the Affected Environment in the past, present, and reasonably foreseeable future, along with appropriate citations and supporting rationale.

the document text provides the necessary information and literature citations to support the conclusions summarized in the matrix cells, so that text and matrix are consistent and securely linked.

D. Evaluating: Determine Significance and Whether Beneficial or Adverse

11. Criteria and thresholds: At this point, all of the cells in the CEA matrix should be completed except those in the far right-hand column (see Table 2b). This column asks whether each identified potential cumulative effect would be significant and, if so, whether the effect would be beneficial or adverse. Value judgments are involved in both determinations, as noted in the following text boxes. To determine whether a potential cumulative effect would be significant, it is important to apply the same criteria and significance threshold that were applied to the predicted direct and indirect effects of the alternatives. This is because the same alternatives and the same resource components are involved. When a determination has been made, enter Yes into the cell if the potential cumulative effect meets the significance criteria and passes the significance threshold. Enter No if the cumulative effect does not qualify as significant. If Yes, place a (+) or (–) to indicate whether the potential significant effect would be beneficial or adverse, respectively, to the resource component being addressed. Finally, provide a bulleted summary in each cell of the key points (criteria) considered in making the significance and beneficial/adverse determinations, with supporting citations. Include the significance threshold and provide an estimate, if feasible, of the approximate percent contribution of the alternative under discussion to the total cumulative effect. This helps to put the alternative into perspective with respect to the total context of all factors contributing to the cumulative effect.

Determining Significance

The CEQ regulations implementing NEPA (40 CFR 1508.27) state that the significance of potential environmental effects should be determined on the basis of *context* and *intensity*. These terms are interpreted in various ways in the literature (see, for example, McMillen 1993). For the purposes of these guidelines, *context* refers to the background conditions and specific circumstances under which the cumulative effect could occur. For example, the significance of predicted wildfire occurrence near human communities might be evaluated as greater than for wildfires in remote locations, and the significance of a predicted small population decline in an endangered species might be evaluated as greater than a comparable population decline in an abundant species. *Intensity* here refers to the severity of the effect and can be based on factors such as magnitude, frequency of occurrence, duration (i.e., long-term versus short-term), and geographic extent (i.e., site-specific versus regional). Clearly, value judgments will have to be applied to determine significance, and the supporting rationale for each value judgment must be documented in the analysis. Using explicit significance criteria, and significance thresholds defined in quantitative terms, will help to ensure consistent understanding of the results among readers with a wide diversity of backgrounds and points of view.

Beneficial or Adverse?

The terms “beneficial” and “adverse” involve value judgments. In the CEA, therefore, it is important to state the supporting assumptions and rationale (criteria) for a determination that a potential effect would be either beneficial or adverse. In many cases, there is a social consensus, supported by the law, regarding what is meant by adverse: for example, air or water contamination, the elimination of habitats that support fish and wildlife populations, or social changes that result in deteriorating health, nutrition, education, or income. Such cases may allow the application of regulatory criteria such as ambient air quality standards, water contaminant standards, etc. that provide objective, measurable thresholds above which a potential effect can be defined as both significant and adverse. Other environmental changes, however–especially in the biological and land use disciplines–may be viewed as either beneficial or adverse, depending on the point of view. For example, because roadside ponding on Alaska’s North Slope can threaten the structural integrity of the roadbed, it could be considered adverse from the standpoint of the physical environment. At the same time, roadside ponding can provide areas of ice-free water that can provide temporary spring habitat for migratory waterfowl and shorebirds returning early in the breeding season, when most lakes and ponds are still frozen. From the standpoint of the biological environment, therefore, the same roadside ponding could be considered beneficial. In general, the first step in making a beneficial/adverse determination is to ascertain whether the potential effect would violate or comply with statutes and documented resource management goals. In the absence of such public policy, the next step is to consider the effect from the standpoint of the particular resource component under consideration and what is considered “good” or “bad” for that resource component. But in all cases, especially those not addressed by laws, regulations, or management policy, the supporting assumptions and rationale for determining whether an effect would be beneficial or adverse must be documented in the analysis.

E. Mitigating, Monitoring and Adaptive Management

The final two steps in the CEA process recommended by the CEQ (1997; see Table 1) are important follow-through actions that, in our experience, are neglected to a varying degree in many NEPA documents. CEQ step 10 calls for the modification or addition of alternatives to mitigate significant cumulative effects, while CEQ step 11 calls for monitoring and adaptive management of cumulative effects for the selected action. With respect to CEQ step 10, the alternatives are almost always modified and sometimes added to in order to incorporate mitigation recommendations resulting from agency and public review of the draft NEPA document. For example, the Draft Programmatic Supplemental EIS for Alaska Groundfish Fisheries (NMFS 2001) is currently being redrafted by the National Marine Fisheries Service to incorporate a modified suite of alternatives approved by the North Pacific Fishery Management Council following extensive public review and comment.

The improvement, with enhanced mitigative measures, of EAs and EISs as a result of the public review process is typically undertaken with diligence, in part because the document can be found deficient during the evaluation undertaken for the Record of Decision (ROD) if this step has been missed. The ROD must “State whether all practicable means to avoid or minimize environmental harm from the alternative selected have been adopted, and if not, why they were not” [40 CFR 1505.2(c)].

Follow-through on step 11, monitoring of the environment to determine whether the predicted or other cumulative effects actually occur, followed by adaptive management to mitigate the observed effects, can require the commitment of costly resources and time. In our experience, this step is frequently left out of the process. From the standpoint of applying CEA as tool for sustainable development, however, the final step is important, because it can provide the feedback necessary to fine-tune and coordinate development proposals in order to minimize adverse cumulative effects that would diminish sustainability.

CEA and Sustainable Development

In our Alaskan NEPA practice, we have seen a growing interest among agency representatives to standardize and coordinate efforts among offices and across jurisdictional lines to develop an integrated, synoptic approach to CEA, so that the results of CEAs can be collated and applied to the planning, review, and permitting of development projects. One of the ideas currently being discussed is to establish a CEA database that would assemble knowledge from various federal, state, and local agencies regarding planned or potential developments, including those in the permitting stage. Among other advantages, an accessible and regularly updated database of this type would help to create a consensus among Alaskan NEPA practitioners in describing the reasonably foreseeable future.

A related idea is to develop a "rolling CEA," an agency-produced and maintained document that is continually revised to reflect the addition of new development projects and natural events to the catalog of factors collectively affecting the moving environmental baseline. This approach might be most useful where applied to a single adaptive management program, such as the recurring amendment of commercial fishery management plans by Fishery Management Councils to anticipate changing ecological conditions such as population cycles of target and non-target species, altered predator-prey relationships, or oceanographic regime shifts.

Interagency coordination of this sort, sharing both information and basic regional planning tools such as geographic information systems, is one of the necessary steps in moving toward the integrative planning of sustainable development. Increasingly in Alaska, agencies are establishing NEPA coordinator positions to facilitate progress in this direction. Another requirement is increased standardization of the CEA process, so that development projects can be compared and data pooled on a common basis. Perhaps most important, there is a need for the institutional mobilization of public and private resources, including non-governmental organizations, in pursuing the goal of sustainable development. Staffing, public involvement, database development, analytic methods, technology, and reporting will have to be standardized, shared, and coordinated to the extent necessary to produce a practical, cost-effective, and tangible result.

Acknowledgements

The authors thank BP Exploration (Alaska) Inc. and the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce for funding projects that led to the ideas described in this paper. The approach presented here has not been formally accepted by government agencies and is not intended to replace or refute guidance by agencies involved with cumulative effects assessments.

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Table 1. Comparison of CEQ (1997) and Modified Approach for Cumulative Effects Assessment

Recommendations from CEQ (1997)	Approach Presented Here
A. Scoping: Identify Issues, Resource Components, and Boundaries	
1. Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals.	1. At the start of the project, hold scoping meetings and interviews with stakeholders, concerned individuals, and the public at large.
2. Establish the geographic scope for the analysis.	2. Review the literature to identify and characterize past, current, and reasonably foreseeable future actions that have affected or could affect the identified resource components, using the scoping input to guide the inquiry.
3. Establish the time frame for the analysis.	3. Identify the relevant resource components for the physical, biological, and socioeconomic environments.
4. Identify other actions affecting the resources, ecosystems, and human communities of concern.	4. Define the geographic scopes for the physical, biological, and socioeconomic environments.
	5. Establish a time scope for the CEA that covers the past, present, and reasonably foreseeable future. Establish the environmental reference point(s).
B. Organizing: Characterize and Consolidate Issues	
5. Characterize the resources, ecosystems, and human communities identified during scoping in terms of their response to change and capacity to withstand stresses.	6. Plan and prepare the Affected Environment chapter. Summarize how the resource components have historically been shaped and altered by human actions and natural events from the environmental reference point up to the present. Note residual effects from the past that continue to influence present conditions.
6. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds	7. Review the predicted direct and indirect effects of the proposed action and its alternatives. Note which are considered significant, beneficial, or adverse, and criteria and thresholds.
7. Define a baseline condition for the resources, ecosystems, and human communities.	8. One alternative at a time, prepare a cumulative effects assessment (CEA) matrix for each resource component.
	9. Enter past, current, and reasonably foreseeable future external influences into the CEA matrix.
C. Screening: Identify Potential Cumulative Effects	
8. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.	10. Enter the appropriate information for each cell in summary form so that potential cumulative effects will become evident.
D. Evaluating: Rank by Magnitude and Probability	
9. Determine the magnitude and significance of cumulative effects.	11. Apply significance criteria and thresholds.
E. Mitigation, Monitoring and Adaptive Management	
10. Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects.	*Same as CEQ step 10.*
11. Monitor the cumulative effects of the selected alternative and adapt management.	*Same as CEQ step 11.*

Table 2a. Procedure for Completing a Cumulative Effects Assessment (CEA) Matrix

For each alternative, prepare matrices that group resource components for the physical, biological, and socioeconomic environments. (The hypothetical example used here applies to selected resource components for the physical environment under Alternative 1, Proposed Action.) Please note that an endangered or threatened species, a particular caribou herd, or other resource component with unique characteristics or special regulatory standing may warrant an individual table of its own to document potential cumulative effects in greater detail.

The following table is an example of a cumulative effects assessment (CEA) matrix. Moving from left to right across the table, the procedure for filling in the matrix is as follows:

Columns ❶ and ❷: This information is based on discussions presented in the Environmental Consequences chapter, Direct and Indirect Effects sections, of the NEPA document (environmental assessment or environmental impact statement). In matrix column 1, provide the topic heading for the type of environmental effect under consideration. In column 2, summarize (a) the predicted direct or indirect effect of the alternative under consideration, (b) whether the effect is predicted to be beneficial (+) or adverse (-), and whether the effect is predicted to be significant (S) or not significant (NS). Reference the supporting text sections of the document.

Column ❸ asks if there is any lingering or persisting effect from a past external influence, whether human action or natural event. This information is based on the results of the past external action research and on the text of the Affected Environment chapter. State whether the effect is beneficial (+) or adverse (-), and cite the appropriate information sources.

In columns ❹ and ❺, summarize each identified external influence to assess if it might have a potential additive or interactive (synergistic) contribution to the listed direct and indirect project effects. State whether the influence is beneficial (+) or adverse (-), and cite the appropriate information sources.

Column ❻ asks if there is a potential cumulative effect. The determination of a cumulative effect results from identifying an additive or interactive process between a predicted direct or indirect effect of the alternative under consideration (column 2) and one or more of the external influences reviewed in columns 3, 4, and 5.

Column ❼ asks whether the potential cumulative effect identified in column 6 would be significant. Enter Yes or No, followed by the rationale you used to make that determination. If Yes, state whether the potential effect is beneficial (+) or adverse (-), with supporting literature citations. Indicate the degree of contribution that the alternative will make to the cumulative effect, relative to the external influences. Reference the document section where the supporting explanatory text can be found.[1]

[1] You may find it works best to write the explanatory text for the Cumulative Effects section after you complete the CEA matrix, allowing the matrix to serve as an organizational tool. Either way, text and table should be securely linked and consistent with each other.

Table 2b. Hypothetical Example of a Cumulative Effects Assessment (CEA) Matrix

Alternative 1: Proposed Action

Physical Resources

❶ Type of Effect	❷ Predicted Direct or Indirect Project Effects?	❸ Persistent Influence from Past External Action or Natural Event?	PRESENT and REASONABLY FORESEEABLE FUTURE EXTERNAL INFLUENCES						❻ Potential Cumulative Effect?	❼ Significant? Beneficial (+) or Adverse (-)?
			❹ Human Actions				❺ Natural Events			
			Existing Project A	**Existing Project B**	**Future Project C**	**Global Pollutants / Arctic Haze**	**Flooding at Spring Breakup**	**Storm Surge**		
DEGRADATION OF AIR QUALITY	Yes (-) (NS) New stationary-source emissions will occur within permitted thresholds *(Citation).*	No	Yes (-) Permitted stationary-source emissions will add to project emissions *(Citation).*	Yes (-) Permitted stationary-source and mobile equipment emissions will add to project emissions *(Citation).*	Yes (-) Emissions from limited mobile equipment operations will add a minor increment to project emissions *(Citation).*	Yes (-) Background levels of gaseous and particulate contaminants will add to project emissions *(Citation).*	N/A	N/A	Yes Project will add to emissions from existing and future projects and to arctic haze *(Citation).*	No • Other projects in area will also fall under New Source Performance standards *(Citation).* • The regulated increase in total emissions will not exceed the ADEC Ambient Air Quality threshold for the North Slope *(Citation).* • The Proposed Action is not expected to contribute measurably to arctic haze *(Citation).*
CHANGES IN SURFACE HYDROLOGY	Yes (-) (S) Construction of a 3.5 km bermed gravel road through wet sedge tundra will block sheet flow, creating ponding on the upstream side and drier conditions downstream *(Citation).*	Yes (-) Gravel roads and pads built to support former projects are still present in the vicinity and produce about 15 km of linear ponding *(Citation).*	Yes (-) Ponding occurs along a 2.7 km portion of the access road to Project A *(Citation).*	Yes (-) Ponding is documented along a 5.2 km portion of the access road to Project B and on the east side of the gravel support pad *(Citation).*	Yes (-) Project C will be built in wet sedge tundra and is expected to block sheet flow along an estimated 4 km. Serial equalization culverts will be incorporated into the project design to mitigate ponding *(Citation).*	N/A	Yes (-) Spring flooding would augment ponding along the access road, and the flooded condition would persist longer than normal because of blockage *(Citation).*	Yes (-) Storm surge would augment roadside ponding *(Citation).*	Yes The additive result of ponding along 3.5 km of the proposed access road in combination with ponding from past and existing projects, spring flooding, and storm surge events would produce an adverse cumulative effect *(Citation).*	**Yes (-)** • The proposed action would add about 3.5 km to the existing 7.9 km of roadside ponding from Projects A and B, an increment of about 44%. This exceeds the cumulative significance threshold of a 10% linear increment in ponding. Additional cumulative effect would result from ponding along gravel roads and pads remaining from past projects and from the future construction of Project C. In total, over 30 km of cumulative ponding would occur, with about 11.5% due to the proposed action *(Citation).* • Spring flooding and storm surge events will increase the volume of impounded water and create a potential for road breaching and washouts *(Citation).* • Ponding from fill placement is considered adverse from a regulatory standpoint, because it alters pre-existing habitats *(Citation).* However, impoundments tend to melt earlier in the spring than natural water bodies and provide beneficial ice-free aquatic habitats for early-arriving migratory waterfowl and shorebirds *(Citation).*
DEGRADATION OF FRESHWATER QUALITY	Yes (-) (NS) Short-term increases in turbidity will not produce lasting changes that exceed ADEC turbidity thresholds *(Citation).*	Yes (-) There is a potential for increased turbidity and sediment load at or near old exploratory pads *(Citation).*	Yes (-) Minor water quality changes (increases in turbidity) have occurred in tundra ponds near this facility *(Citation).*	Yes (-) Lead and chromium concentrations slightly above background levels have been detected in tundra ponds near this facility *(Citation).*	Yes (-) Localized water quality changes, which can be mitigated, are expected to result from construction and operation of Project C *(Citation).*	N/A	Yes Flooding could distribute water quality contaminants *(Citation).*	Yes Storm surge could distribute water quality contaminants *(Citation).*	Yes Local sediment and contaminant releases from other projects could add to small sediment and contaminant releases from Proposed Action and be exacerbated by flooding and storm surge *(Citation).*	No • Turbidity increases will be minimized by winter construction and will not cumulatively exceed ADEC thresholds *(Citation).* • Incremental contaminant releases by the Proposed Action, if any, would be too small to increase cumulative background levels *(Citation).* • Effects of flooding and storm surge may temporarily increase turbidity but will not lead to cumulative increases in water quality contaminants in combination with the Proposed Action *(Citation).*
CHANGES IN PERMAFROST SOILS	Yes (-) (NS) Localized thermal erosion is expected and will be minimized by standard permafrost construction techniques *(Citation).*	Yes (-) Past construction of roads and pads has led to persistent but localized thermal erosion, slumping, and thermokarst *(Citation).*	Yes (-) Site-specific cases of thermal erosion have been documented for this project *(Citation).*	Yes (-) Site-specific cases of thermal erosion have been documented for this project *(Citation).*	Yes (-) Localized thermal erosion is expected and will be minimized by standard permafrost construction techniques *(Citation).*	N/A	N/A	N/A	Yes Unintended changes to permafrost soils could result even with mitigative construction techniques, but they are expected to be minimal *(Citation).*	No • Changes in permafrost soils from new construction will be avoided or minimized and, where they do occur, site-specific *(Citation).* • No additive or interactive cumulative effect is predicted from localized cases of thermal erosion resulting from former or new construction *(Citation).*