The Before-After Dose-Response (BADR) Monitoring Framework: At a Glance

1.0 Terrestrial Biological Monitoring and BADR

One of the theme areas monitored within the OSM program is terrestrial biodiversity, known programmatically as Terrestrial Biological Monitoring (TBM). Biodiversity refers to the diversity of wild species, habitats, and ecosystems. These biological resources provide incredible value, including cultural and spiritual, recreational, subsistence, and ecosystem services.

A Hierarchical Before-After Dose-Response (BADR) study design was developed to provide an integrated, efficient framework for the TBM program. The framework is used to address the following key questions in terrestrial ecosystems:

1. Have changes occurred?
2. To what degree are those changes attributable to oil sands activities?
3. What are the cumulative effects of oil sands stressors?

The BADR framework represents a major shift in how terrestrial ecosystems are monitored in the oil sands region and is directly aligned with addressing these three questions using indicator groups that are directly aligned with the conceptual model.

2.0 What is BADR?

BADR is a monitoring design that measures changes in selected indicator groups and attributes those changes to oil sands activities using two monitoring approaches:

1) **Before-After**: Monitoring at different phases of oil sands development (currently developed, not yet developed, and reference)
2) **Dose-Response**: Monitoring along a gradient of current oil sands disturbance (high to low)

The combination of these two approaches forms the BADR design. By repeatedly surveying monitoring locations within this design over time, we will gain information on how biological systems are changing as oil sands activity changes.

3.0 What BADR Measures

Change will be measured for a number of indicator groups, which fall into three categories: stressor, pathway, and response. Stressor indicators provide information on the state of oil sands stressors, pathway indicators inform the mechanisms by which those stressors impact ecosystems, and response indicators represent aspects of the environment that are susceptible to changes due to oil sands activity. Stressor, pathway, and response indicators have been selected for the priority linkages within the OSM conceptual model for each of the four indicator groups.

Stressor Indicators	
Indicators	Parameters
Landscape disturbance	Land use and land cover data Human footprint inventories
Natural disturbance	Disturbance indices: fire, disease, drought
Contaminants*	Air, water, sediment, and snowpack contaminants
Physical infrastructure	Off lease: above-ground pipelines, noise, light
Climate change	Projections and recent observations of climate change

Pathway Indicators	
Indicator Groups	Indicators
Linking landscape disturbance with responses	Habitat loss, degradation, and recovery Behaviour related to reduced habitat connectivity Invasive species
Linking infrastructure with responses	Behaviour
Linking contaminants with responses*	Chemicals in lichen tissue Periphyton and aquatic macrophyte contaminants Mammal contaminant burdens in tissue, fur, feces Mammal health Contaminant levels in colonial waterbird eggs Wood frog tadpole tissue contaminants; water, aquatic invertebrates, and sediment contaminants
Linking climate change with effects on valued components	Increased frequency and severity of wildfire with deposition of contaminants Changes in habitat leading to changes in wildlife

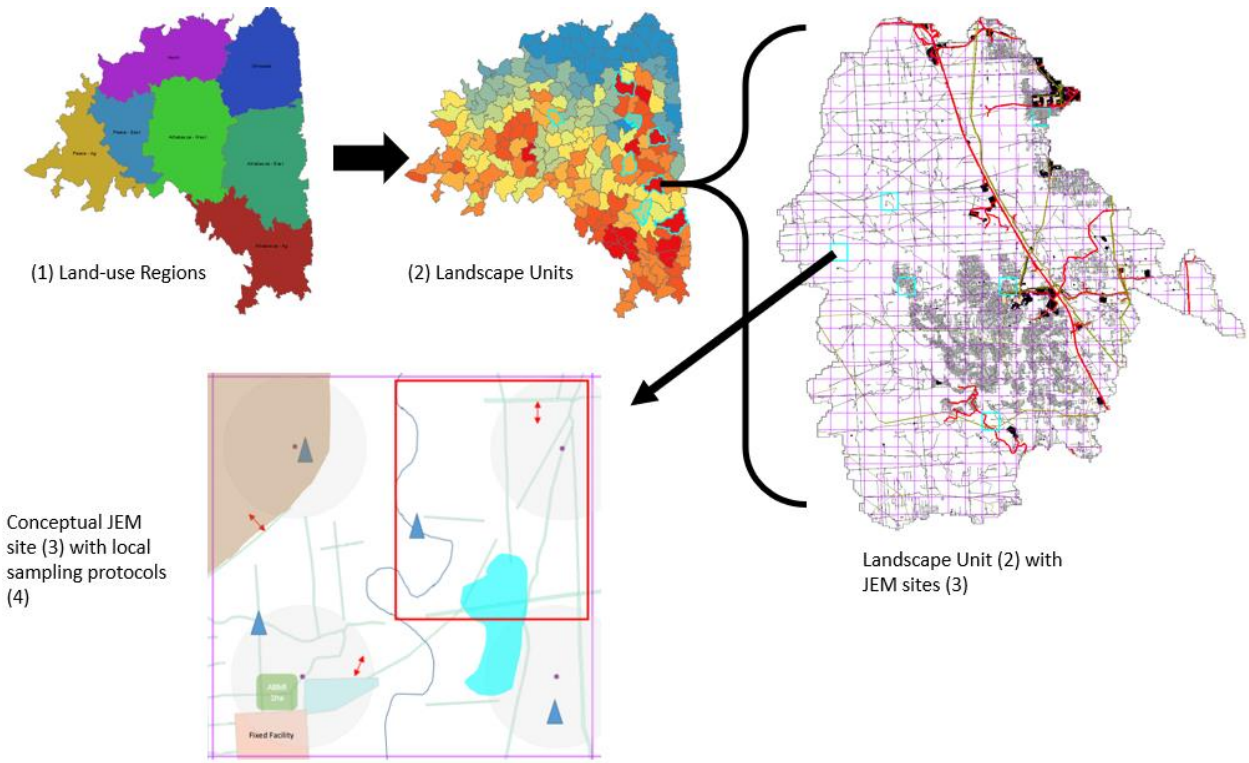
Response Indicators	
High-level Indicator Groups	Indicators
Vascular Plants, Mosses, Lichens	Height, cover, growth, species richness, community composition, density, structural complexity
Migratory Landbirds	Population growth rate (productivity, survival, recruitment), occupancy/density, habitat selection, functional group or guild abundance, species richness/diversity
Mammals	Occupancy, abundance, distribution, habitat selection, reproduction
Amphibians	Relative abundance

*Contaminant sampling for mammals will be a collaborative effort between TBM and Community Based Monitoring Programs with Indigenous communities, hunters, and trappers. Contaminant stressor and pathway indicators will be collected in collaboration with the Air and Deposition, Water, and Wetlands Themes (details to be confirmed).

4.0 How BADR Works

BADR is used to decide where to put monitoring locations. This process occurs using a nested spatial hierarchy, which includes:

1. Dividing sampling across the oil sands region into large **Land-use Regions**: These Regions capture broad differences in oil sands activities and ecological context. Sampling across these regions ensures coverage for the full spectrum of oil sands stressors.
2. Focusing sampling effort into specific **Landscape Units**: Landscape units are based on watershed boundaries and are ranked according to oil sands footprint intensity. Landscape Units are selected to capture areas with low to high current oil sands footprint, and where oil sands stressors are expected to increase in the future.
3. Identifying specific locations to sample called Joint Environmental Monitoring - **JEM sites**: JEM sites are shared monitoring locations used by multiple agencies to centralize data collection. JEM sites are used to target specific oil sands disturbance types and intensities.
4. Placement of **local sampling protocols**: These are the specific locations where individual protocols will be implemented to collect data for different ecological indicators.



5.0 BADR for Specific Questions

The monitoring of some organisms or habitats requires consideration of spatial scales outside the structure of BADR due to their life history (e.g., behaviour, space-use, home-range size). Currently, the following complementary, targeted programs operate alongside BADR:

- Rare Habitat Program: A set of sites targeted to rare habitats in order to gather sufficient data on rare species and how they are changing over time
- Aerial Ungulate Surveys: Standardized surveys to monitor critical survival and productivity information for ungulates, conducted at the Wildlife Management Unit scale
- Mortality Risk to Endangered Species: Whooping Crane monitoring project to assess risk of tailings ponds to this Endangered Species
- Contaminants: Samples will be collected from mammals, amphibians and colonial waterbirds to assess contaminant levels and provide information on food safety and security and the health status of harvested species.

6.0 Conclusion

The BADR design ensures that the three monitoring questions listed in Section 1 are addressed in an effective, consistent, and credible manner. The design was developed to:

- use an ecologically relevant landscape spatial unit – watersheds;
- examine change along stressor gradients at various spatial scales;
- include reference (low dose) sampling units;
- include indicators at the individual, population, and community level;
- incorporate areas of planned oil sands expansions; and,
- produce results which can be used for model validation

The Hierarchical BADR design will contribute scientific information to help judge the efficacy of existing regulations and compliance with approvals as they apply to “beyond the fence line” responses to oil sands stressors at local, sub-regional and regional scales.