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Abbreviations and Acronyms

AER	Alberta Energy Regulator
AMU	Aquifer Management Unit
APEGA	Association of Professional Engineers and Geoscientists of Alberta
ASET	Association of Science and Engineering Technology Professionals of Alberta
BGWP	Base of Groundwater Protection
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
EPEA	*Environmental Protection and Enhancement Act*
PHC	Petroleum Hydrocarbon Fractions
QA/QC	Quality assurance and quality control
TDS	Total dissolved solids

Definitions

Aquifer Management Unit	Non-saline aquifer that has identified risks associated with it and has been selected for additional monitoring
Baseline Condition	For the purpose of this document, baseline condition means groundwater quality and quantity prior to being altered by subsurface heating from the facility's operations.
Director	An employee of the Alberta Energy Regulator or the Government of Alberta designated as the delegated authority under *EPEA.*

Heat Source	The location where steam injection occurs.
Indicator Parameter	A subset of parameters that indicate those chemical parameters that have mobilized due to subsurface heating.
ISO/IEC 17025	International standard, developed and published by International Organization for Standardization (ISO), specifying management and technical requirements for laboratories
Monitoring Area	An area that is deemed to have higher risk within the project area where proposed monitoring shall occur
Non-saline Water	Water with 4,000 mg/L or less of total dissolved solids.
Parameter	A measurable variable used to verify that the outcomes are being met.
Point of Compliance	The location where baseline conditions shall not be exceeded. The point of compliance will not exceed 1,000 metres down gradient of the Heat Source, or the distance to the nearest identified receptor, whichever is less.
Point of Management	A point between the Heat Source and the point of compliance where management action is required should a trigger be confirmed at the Heat Source.
Trigger	Early warning of a negative change in condition from natural variability in aquifer conditions.

1 Introduction

Many chemical constituents are present naturally in sediments and groundwater throughout Alberta and, given the appropriate conditions, have the ability to be mobilized from the host sediments by subsurface heating. As thermal in situ oil sands production became established in the late 1990s, increased levels of arsenic were observed in groundwater down gradient of several steam injection wells. These elevated arsenic concentrations have been attributed to the heating of subsurface sediments and subsequent release of arsenic to groundwater. Ongoing monitoring at these sites has provided preliminary information about this phenomenon and additional studies have reported similar behavior for other constituents. Similar effects to groundwater are anticipated for other in situ projects. Given the mobilized constituents are naturally-occurring in the sub-surface, such effects are manageable if they are contained within a limited area, do not impact receptors, and are reversible over the long-term. Careful monitoring and management shall be implemented to ensure this.

The *Directive for the Assessment of Thermally-Mobilized Constituents in Groundwater for Thermal In Situ Operations (Directive)* was developed to ensure that appropriate monitoring and management occurs through the development and implementation of site-specific Project Assessments and Groundwater Monitoring Programs for all thermal in situ operations.

1.1 Regulatory Linkages

This *Directive* was developed in accordance with the requirements of the *Environmental Protection and Enhancement Act (EPEA)* and is one component of a large initiative to manage cumulative effects to groundwater quality and connected surface water sources on a regional basis. A key objective of this *Directive* is to prevent impacts to regional groundwater resources and surface water bodies by managing, at the local level, potential impacts of thermally mobilized constituents for thermal in situ operations.

The *Lower Athabasca Region Groundwater Management Framework* (*Framework)*[1] describes the regional-scale monitoring and management of groundwater. The *Framework* describes how site-specific activities are an integral component of the regional-scale management of groundwater. Site-specific monitoring is intended to identify and manage localized effects on groundwater resources and to prevent such effects from manifesting on a regional scale.

The *Framework* refers to a suite of regional monitoring indicators and interim triggers and a regional management response, all of which are components of the regional groundwater management system led by the Government of Alberta. This *Directive* refers to site-specific indicators, triggers, and management responses to be developed and implemented by the approval holder for the management of groundwater quality on their site.

Any reference to the *EPEA, Framework* or other regulatory documents in this *Directive* shall mean the most recent available version at the date of submission of the Project Assessment, Groundwater Monitoring Thermal Proposal, Groundwater Monitoring Thermal Report or Groundwater Monitoring Report.

1.2 Purpose and Application

This *Directive* provides the requirements for the development of site-specific Project Assessments and Groundwater Monitoring Programs to address the potential thermal mobilization of constituents at in situ oil sands recovery facilities. It provides a standard approach to assess and manage risks to groundwater quality associated with steam injection, focusing on potential effects resulting from the heating of the vertical component of the well

[1] The documents mentioned do not represent an exhaustive list of applicable legislation, regulations, policies, standards or guidelines that helped to inform and shape this *Directive*

bore and conduction of that heat into adjacent formations (Figure 1). This *Directive* includes requirements for site-specific management, including assessment, monitoring, and reporting.

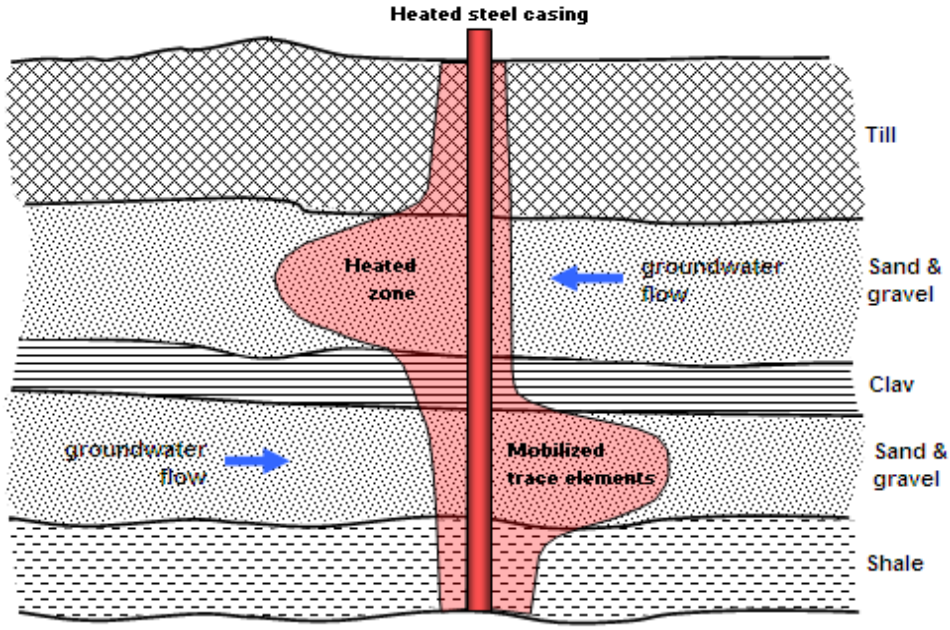

Figure 1: Conceptual Schematics of Heated Zone Generated by a Thermal In Situ Steel Casing

The objective of this *Directive* is to ensure that Groundwater Monitoring Programs are developed and implemented such that thermal and chemical effects associated with the heating of aquifers during thermal in situ oil sands recovery are contained within a specified area, ensuring protection of receptors, and that all effects are eventually stabilized and reversed such that baseline groundwater quality conditions are restored.

This *Directive* pertains only to groundwater quality and only applies to non-saline groundwater. Groundwater is considered to be non-saline if it has a mineralization of 4,000 mg/L total dissolved solids (TDS) or less. The Base of Groundwater Protection (BGWP) identifies the depth of non-saline groundwater is likely to occur within Alberta. However, it is important to note that non-saline groundwater may also occur locally in aquifers below the defined BGWP[2] (AER Bulletin 2007-10) and therefore this *Directive* is not limited by the BGWP.

This *Directive* applies to new and existing projects. A project is considered to exist if an *EPEA* approval has been issued before the Effective Date of this *Directive*. Approval applicants that have submitted an application currently within the approval process are encouraged to contact the Director for applicability purposes. For both new and existing projects, this *Directive* applies to the plant as defined within the project's *EPEA* approval. If a phased development approach is proposed, this *Directive* shall be implemented for each new phase as it is developed.

Information gathered will be used by AER as part of approval applications for *EPEA* authorizations. To ensure that impacts or potential impacts are properly managed, the Director may require a period of more stringent

[2] AER Bulletin 2007-10: Alberta's Base of Groundwater Protection (BGWP) Information

monitoring and reporting. For the purpose of this *Directive*, the Director is defined as an employee of AER designated as the delegated authority under the *EPEA.*

Under the existing regulatory process, approval applicants may be expected to prepare an Environmental Impact Assessment (EIA) report if required to do so under Division 1 of the *EPEA.* If an EIA is not required, approval applicants shall be expected to conduct an Environmental Assessment as part of their *EPEA* application as outlined in the *Guide to Content for Energy Project Applications*. This Environmental Assessment shall be expanded to include the requirements of this *Directive.*

The applicability of each component of this *Directive* will depend on the complexity of the geological and hydrogeological conditions of the plant. Therefore, a professional for the proponent, registered with the Association of Professional Engineers and Geoscientist of Alberta (APEGA), shall determine the components of this *Directive* applicable to the project, recognizing that they will be required to justify to the Director the exclusion of any component, based on their professional judgment.

1.3 Background

Mobilization of constituents from sediments into groundwater can occur either as direct dissolution or weathering of a mineral phase, or via the release from a mineral surface as a result of physical, chemical, and/or biological processes. Because temperature is an important factor influencing these release mechanisms, mobilization potential from host sediments beneath thermal in situ projects must be assessed, and may require further monitoring and management should constituent mobilization be confirmed. Natural attenuation of constituents mobilized during thermal in situ operations is expected to occur through re-absorption by the surrounding sediments after heating effects have dissipated, possible mineral precipitation reactions, and as a result of hydrodynamic dispersion (i.e., mixing with natural formation water resulting in reduced concentrations).

Constituents of interest related to thermal mobilization are those that occur naturally in the subsurface host sediments and are either found in groundwater under ambient conditions or have the potential to be mobilized into the groundwater when heated. There are number of constituents with the potential to become mobilized into the groundwater environment as a result of elevated subsurface temperatures. However, a number of conditions are required before this can occur:

- The constituents must be available in the host sediments.
- The constituents must be available to be mobilized, which will be influenced by where and how they are associated with the host sediments (i.e., occluded into the surface layers of a mineral; adsorbed onto a mineral surface).
- The geochemical conditions must be appropriate for mobilization from the host sediments (e.g., changes to pH, redox, and microbial activity).

Following the introduction of heat to the aquifer, it is anticipated that temperature increases will precede any thermal mobilization of constituents. Temperature fluctuations should be considered as an early indicator as to the onset of mobilization of constituents.

1.4 Management Approach

The release of harmful or altering substances into groundwater is generally not acceptable in any situation. For most industrial operations, groundwater quality may be impacted through the unintentional release of a substance due to infrastructure failure, operational upset, or a secondary effect related to the release of another substance.

However, for thermal in situ operations, while there is the potential for effects to groundwater due to unintentional releases, there may also be a predictable effect due to the nature of the operation (i.e. the heating of the subsurface.) It is therefore anticipated that within a limited proximity of the Heat Source associated with each steam injection pad (herein referred to as the Management Area) there may be a change in the quality of groundwater due to the thermal release of constituents present naturally in the sediments. These localized effects are considered acceptable due to the constituents being naturally occurring in the mineral phases of the sediment, or associated with mineral surfaces, and no new substances are being introduced into the sub-surface environment. Furthermore, many of these effects are expected to be reversible on a human time-scale. Within this same area, effects due to the release of substances not naturally occurring (e.g., casing failure, surface spill) remain subject to Part 5 of *EPEA*.

Monitoring, modelling and other tools will be used to identify and evaluate increasing trends at a local scale. Emphasis will be placed on site-specific management of groundwater quality which will be based on the quantification of baseline conditions and site-specific triggers. The purpose of establishing baseline conditions for indicators is to properly understand the range of natural variability to allow detection of potential changes to groundwater quality. Indicators provide information about whether site-specific objectives are being met and allow approval applicants/holders and the Director to assess and track any changes to the groundwater resources.

Baseline conditions shall be established for indicator parameters in each aquifer being monitored. An increasing trend that extends beyond the quantitative range of natural variability indicates that changes in the local groundwater system are occurring and clearly defines the point at which the approval holder is required to respond.

Not all non-saline aquifers and well pads require groundwater monitoring within the plant area. Approval applicants shall conduct a screening process to identify aquifers and well pads which shall require additional monitoring. This screening process is based on the evaluation of sources, pathways and receptors and shall be considered a component of the Project Assessment[3].

1.5 Management Area

The Management Area represents the area of potential effect where constituents may be expected in concentrations above baseline conditions throughout and beyond the operational life of the steam injection pad. The Management Area shall define the area where monitoring and management efforts will be focused. The Management Area for each monitoring location shall consist of a minimum of three locations:

- Heat Source Well
    - Located within 20 m of the Heat Source, and in the down-gradient direction (estimated or established);
    - Alternate downgradient distances between 20 m and 50 m may be approved by the Director[4];
    - Thermal effects are anticipated to be observed within the first year of operations within the Heat Source monitoring well.
- Point of Management Well

[3] For existing projects components of the Project Assessment are to be included in the Groundwater Monitoring Thermal Report

[4] For existing projects with several years of steaming, alternate downgradient distances of 50 m or greater may be justifiable and approved by the Director

- Located downgradient of the Heat Source, and within a distance that will be subject to changes in groundwater conditions within five (5) years of installation. The well shall be positioned between the Heat Source monitoring well and the Point of Compliance; and
- Up-gradient of any significant receptor identified down-gradient of the Heat Source.

- Point of Compliance Well

  - Located where baseline conditions shall not be exceeded;
  - Location will not exceed 1,000 m down gradient of the Heat Source, or the distance to the nearest identified receptor, whichever is less.

Staged monitoring and modelling activities shall be used to define these three locations, as described in Sections 3 and 4. Approval applicants and holders are encouraged to use existing infrastructure and land disturbance as much as practical in order to reduce additional land disturbance.

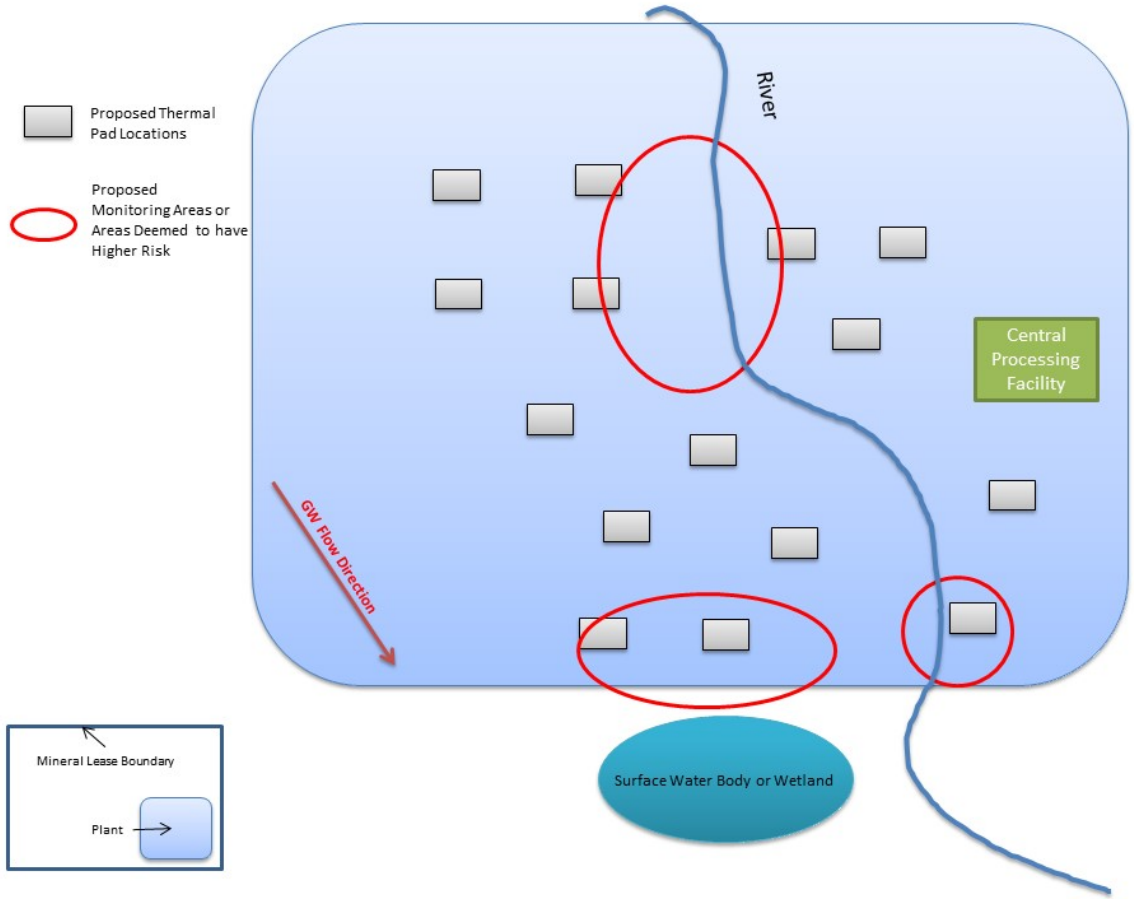

Figure 2: Conceptual diagram showing examples of Management Areas where monitoring occurs

The Point of Management is intended to facilitate understanding of heat and constituent behavior in the targeted aquifers through ongoing monitoring and iterative modelling activities. This work will assist the approval holder in predicting, understanding, and mitigating potential effects at the Point of Compliance.

Groundwater quality is to be maintained within baseline conditions at the Point of Compliance. Monitoring and modelling work taking place at the Heat Source and Point of Management should provide sufficient indication of what effects, if any, may be expected at the Point of Compliance such that early action can be taken to assess the

risks of such effects and initiate any necessary mitigative actions. If chemical effects are observed at the Point of Compliance, the approval holder shall initiate response actions (Section 7).

1.6 Aquifer Management Units

Aquifer Management Units (AMUs) are defined at those non-saline aquifers within the management area where effects associated with the heating of the subsurface are expected to be observed and have been selected for additional monitoring. Approval applicants and holders are not expected to monitor every non-saline aquifer but rather those that have been deemed to have higher risk. Those deemed to have higher risk based on criteria such as but not limited to:

- water quality;
- location of receptors; and
- groundwater usage.

Approval applicants and holders are not expected to monitor AMUs at every well pad but rather those selected based on criteria such as the location of receptors and other risks. Outside of the management area, baseline conditions are to be maintained within these non-saline aquifers as the aquifer will no longer be considered an AMU.

2 Project Assessment

The Project Assessment shall be used by the Director as part of the application process for *EPEA* approvals and shall be submitted with the approval application. Approval applicants may be required to collect additional data for the Project Assessment at the discretion of the Director. Requirements for existing facilitates are outlined in Section 9.2.

For the most part, the Project Assessment shall be based on known geology, hydrogeology, geochemistry, groundwater flow patterns and rates, and any other available information, primarily on a regional scale. Site-specific information, such as proximity to receptors, density of heat sources and resulting potential for co-mingling plumes, or groundwater flow patterns and rates, should also be used. For example, local geological information derived from required geophysical logging programs pursuant to AER *Directive 080: Well Logging*, and other sources, should be included in the evaluation. The level of detail will need to be appropriate for the size of the project and the anticipated risk.

2.1 Information to be Included in the Project Assessment

Approval applicants shall include in the Project Assessment the following, at a minimum:

- conceptual hydrogeologic model;
- proposed AMUs;
- identification of receptors;
- proposed monitoring locations or delineated areas where Heat Source monitoring wells will be located;
- proposed Management Area for each monitoring location with justification, as available;

- proposed Management Area for delineated areas if monitoring locations are not known with justification; and,
- list of parameters.

2.2 Receptors

Approval applicants shall conduct an assessment to determine locations of receptors within the plant and within a radius of no less than 1,000m from the Heat Source. This review shall identify existing water well records, springs, and surface water features, and may use any available information such as recently flown aerial photographs, satellite images, field reconnaissance programs, information provided by local indigenous communities or local geological information derived from geophysical logs and seismic surveys.

Potential receptors include, but are not limited to:

- well being used for domestic, municipal or camp supply, irrigation or livestock watering;
- wetland or wetland complex that is potentially influenced by groundwater discharge (i.e. marsh, fen swamp, or shallow open water wetland);
- traditional land use features associated with groundwater (i.e. springs, wetlands, groundwater discharge areas)
- surface water body (stream, river, or lake) that is potentially influenced by groundwater discharge; and,
- non-saline aquifers located outside of the Management Area.

2.3 Conceptual Hydrogeologic Model

Approval applicants shall create a conceptual hydrogeologic model for the aquifer system which includes the identification of non-saline aquifers within the plant associated with those receptors identified under Section 2.2. Non-saline groundwater may occur locally below the BGWP where non-saline aquifers are in communication with deeper saline aquifers, such as buried Quaternary channels. Areas where non-saline groundwater is suspected to exist at depths greater than those identified by the BGWP shall be identified by the approval applicant. The hydrogeological conceptual model shall include the following if known:

- groundwater-surface water interactions;
- hydraulic connectivity between aquifers;
- lateral and vertical extent of each aquifer;
- regional and local flow systems;
- hydraulic conductivities and transmissivities;
- designation as a confined or unconfined aquifer; and,
- Quaternary channels.

2.4 Aquifer Management Units

Approval applicants shall identify those aquifers to be selected for monitoring. A non-saline aquifer could be identified as an AMU if it is:

- potentially regional in scale;

- is being used or has the potential to be used for domestic supply or agricultural purposes (i.e. high yield, high quality);
- traditional land use features associated with groundwater;
- is known to or has the potential to discharge to a wetland or wetland complex (i.e. marsh, fen, swamp or shallow open water wetland);
- is known to or has the potential to discharge to a surface water body (e.g., stream, river, or lake); or
- is of high permeability (e.g. glacial outwash sands and gravels, buried channels), or is influenced by aquifers of high permeability.

2.5 Monitoring Location and Area

The associated effects posed by thermally-induced constituent mobility are not the same for every site. Based on the information gathered in Sections 2.2 to 2.4, approval applicants shall propose monitoring locations where the potential effects will be evaluated in greater detail following the criteria outlined in Section 1.5. If exact monitoring locations are not known at the application stage, approval applicants may outline areas where Heat Source monitoring wells shall be located.

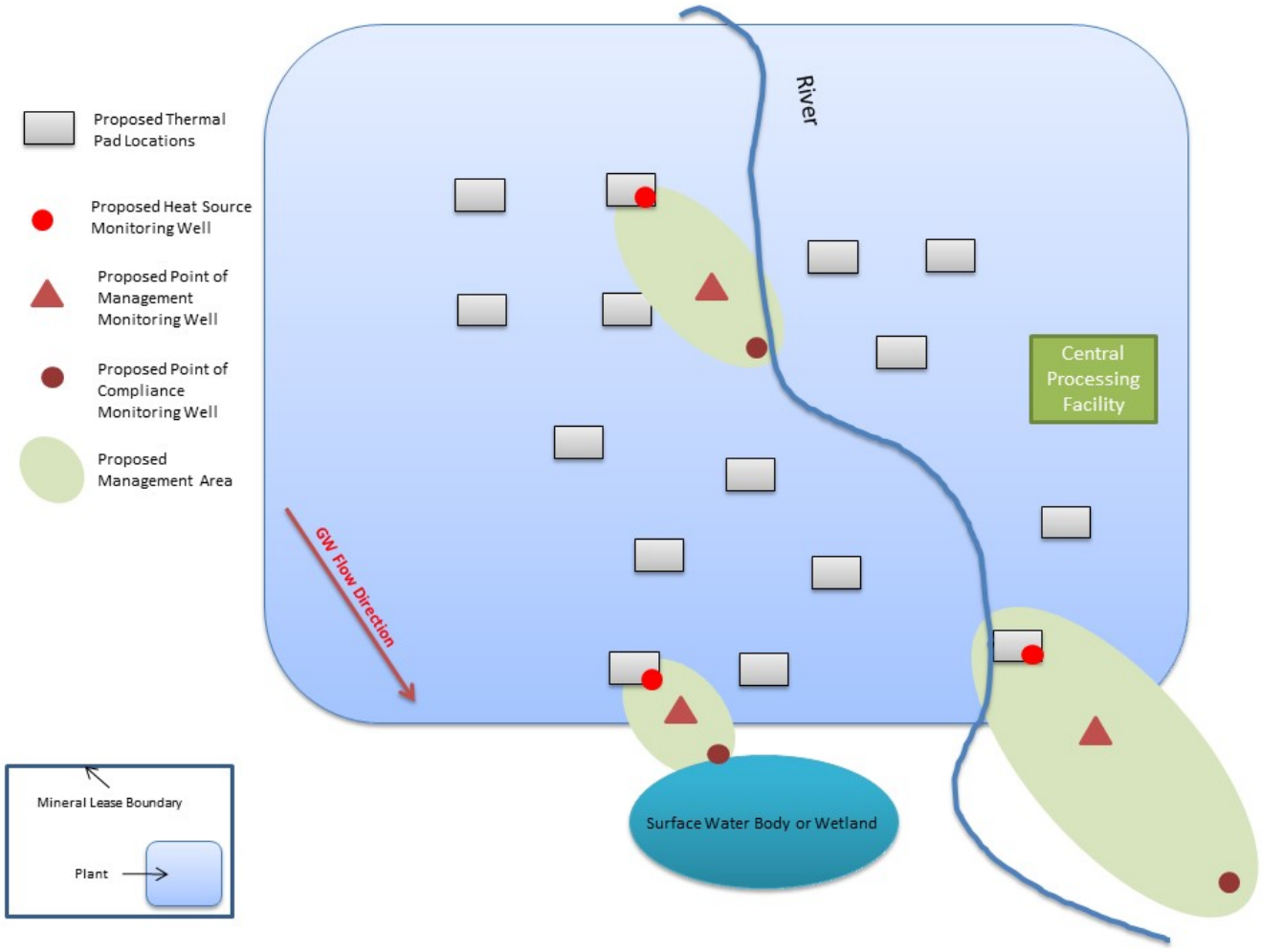

Figure 3: Conceptual diagram showing examples of areas with proposed monitoring area/locations.

2.6 Parameters and Indicators

Indicators are used to describe and assess the physical conditions and chemical characteristics of groundwater and shall be subject to monitoring and management outlined in this *Directive.* Approval applicants shall provide a list of parameters to be monitored which shall include at a minimum:

- Physical Parameters:
    - Static water levels
    - Temperature
    - pH
    - Total Dissolved Solids (TDS)
- Chemical Parameters:
    - Major ions
    - Trace elements/metals scan by ICP
    - Naphthenic acids
    - Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)
    - Petroleum Hydrocarbon Fractions (PHC) F1 and F2

Indicator parameters are those chemical parameters that have mobilized due to subsurface heating, as detected in the Heat Source monitoring wells. The list of indicator parameters may be expanded over time if additional parameters are mobilized at the Heat Source. Conversely, not all thermally mobilized indicator parameters pose an environmental or health risk to potential receptors and the list of indicator parameters may be reduced at the discretion of the Director. Indicator parameters shall be identified after thermal effects have been observed and submitted within the regular Groundwater Monitoring Reports.

Although physical parameters are not considered to be indicator parameters, they should be considered early warning indicators.

3 Groundwater Monitoring Program

Upon receiving approval, the approval holder may begin the construction phase of their project. During this period, approval holders shall develop a Groundwater Monitoring Thermal Proposal as part of the facility's *EPEA* Groundwater Monitoring Program Proposal including a detailed monitoring and assessment program for thermal mobilization of constituents. [5] The Groundwater Monitoring Thermal Proposal shall include a detailed monitoring program and shall be phased such that increasing levels of investigation, evaluation and management are required for aquifers that require additional monitoring. The Groundwater Monitoring Program will apply to AMUs which were identified in the Project Assessment.

3.1 Information to be Included in the Groundwater Monitoring Thermal Proposal

Approval holders shall include in the Groundwater Monitoring Thermal Proposal the following at a minimum:

- updated information provided in the Project Assessment
    - conceptual hydrogeologic model;

[5] For existing projects relevant components of the Groundwater Monitoring Thermal Proposal are to be included in the Groundwater Monitoring Thermal Report (see Section 9.2)

    - identification of receptors;
    - list of parameters;
    - Management Area for each AMU;

- AMU characterization at heat source;
- triggers at the Heat Source;
- description of proposed response actions at the Heat Source;
- description of proposed monitoring activities and response actions at the Point of Management and Point of Compliance; and,
- Groundwater Monitoring Report submission frequency.

3.2 Aquifer Characterization

Observing and understanding effects of sub-surface heating at the Heat Source itself provides insight about potential effects that may be expected at greater distances and allows for early data collection that can be used to inform future monitoring and modelling activities.

The approval holder shall install at least one Heat Source monitoring well at each selected monitoring location/area into those AMUs identified in the Project Assessment. The Heat Source monitoring well(s) shall be located no more than 20 m down-gradient of a steam injection well. An alternate distance up to 50 m downgradient may be approved by the Director provided that the approval holder has provided site-specific data which warrants a greater distance[6].

Approval holders shall complete a hydrogeological characterization of each AMU which shall include the following:

- Static water levels;
- Hydraulic conductivity;
- Hydraulic gradient;
- Groundwater flow direction; and
- Groundwater velocity.

Methods used for determining this aquifer-specific hydrogeological information shall be described within the Groundwater Monitoring Thermal Proposal or Groundwater Monitoring Report.

Approval holders shall characterize the condition of groundwater quality for each AMU at the Heat Source prior to the commencement of steam operations. At least three (3) monitoring events collected at a frequency of no more than once per month will be required to adequately characterize each AMU for all physical and chemical parameters identified in Section 2.6. These three monitoring events shall be used to establish a point of reference representing pre-steaming conditions. Applicant holders may be required to conduct more sampling at the discretion of the Director.

[6] For existing projects with several years of steaming, alternate downgradient distances of 50 m or greater may be justifiable and approved by the Director

3.3 Heat Source

Triggers set at Heat Source are used to signal when the approval holder shall undertake a more detailed assessment and additional monitoring. The following triggers are to be used:

Trigger 1:

- Change in concentration of a chemical parameter that indicates an increasing trend at a Heat Source monitoring well

Any chemical parameters that are confirmed under Trigger 1 are to be used as indicator parameters as described in Section 2.6. Although a change in temperature is not considered to be a trigger that requires a response action, approval holders are required to continue to monitor temperature in addition to other physical parameters. Changes in temperature could be considered to be an early indicator that concentrations of chemical parameters may change. When increasing temperatures are observed approval holders may increase their monitoring frequency to capture the early mobilization of constituents.

3.4 Monitoring Requirements

Upon the establishment of triggers for each AMU at the Heat Source, approval holders shall continue to monitor each AMU. The frequency of monitoring shall be based on hydrogeological conditions that would allow for the confirmation of any triggers. However, at a minimum, groundwater quality and temperature shall be monitored at a quarterly basis once steam injection has commenced. The Director shall be notified of any trigger confirmations within 30 days and the response actions outlined in Section 4 shall be implemented.

3.5 Groundwater Monitoring Reports

Approval holders shall submit a Groundwater Monitoring Report to the Director at a frequency specified in the facility's *EPEA* approval and outlined in the Groundwater Monitoring Thermal Proposal. As part of each Groundwater Monitoring Report, approval holders shall evaluate monitoring well data on an ongoing basis to identify the development of trends. Once effects have been observed at the Point of Management groundwater modelling shall be used to understand and predict the long term effects of the operations.

4 Management Response

The following sections outline the monitoring requirement for each stage of monitoring within the management area.

4.1 Heat Source

4.1.1 Management Response at Heat Source

The approval holder shall implement the following site-specific management responses after confirmation of Trigger 1:

- Submit notification letter within 30 days;
- Maintain or increase the frequency of sampling for all parameters to a quarterly basis at a minimum;
- Take an initial temperature profile of the deepest well, representing the vertical depth of the water column;

- Re-verify the hydrogeological characterization which shall include the following:
    - static water levels;
    - hydraulic conductivity;
    - lateral hydraulic gradient;
    - groundwater flow direction; and
    - groundwater flow velocity.
- Within twelve (12) months of confirming Trigger 1 in an AMU, install monitoring well(s) at the Point of Management into the affected AMUs; and,
- For each aquifer where Trigger 1 is confirmed, submit the following information to the Director as part of their next regularly submitted Groundwater Monitoring Report.
    - Proposed list of "indicator parameters" (i.e. those parameters that have mobilized at the Heat Source) for ongoing monitoring, statistical analysis and reporting at the Point of Management and Point of Compliance. The list of indicator parameters may increase if additional constituents are later mobilized;
    - Vertical temperature profile;
    - Point of Management location, respecting the criteria provided in Section 1.5;
    - Sampling frequency for all parameters at the Heat Source until monitoring has commenced at the Point of Management; and
    - Predicted time of arrival of the chemical plume at the Point of Management for all indicator parameters.

4.2 Point of Management

4.2.1 Monitoring Requirements at the Point of Management

Approval holders shall establish the Point of Management downgradient of Heat Sources at a location that facilitates detection of expected change in groundwater conditions within five (5) years. The approval holder shall install a monitoring well in each AMU at the Point of Management within twelve (12) months of Trigger 1 being confirmed at the Heat Source.

Approval holders shall establish baseline conditions. Baseline sampling should be established by using samples taken at a quarterly frequency to ensure that seasonal influences are accounted for. More frequent samples may be taken but should not be used to establish baseline in a shorter period of time. The position of the monitoring well(s) and sampling frequency at the Point of Management shall be such that the entire baseline data set shall be collected prior to any effects reaching and influencing the monitoring well. Baseline conditions are to be determined using an appropriate statistical method once sufficient data is collected. The Director may request that the approval holder take a temperature profile in the deepest well, representing the vertical depth of the water column, to better understand the distribution of heat in the aquifers and confirm the selection of higher risk aquifers for monitoring.

Once baseline conditions have been determined for each monitoring well at the Point of Management, the approval holder shall continue to monitor indicator parameters and physical parameters semi-annually, at a minimum.

4.2.2. Triggers at the Point of Management

A further trigger shall be set at the Point of Management, representing the second trigger in the overall management system:

Trigger 2:

- Change in concentration of an indicator parameter from baseline that indicates an increasing trend at a Point of Management well

Although a change in temperature is not considered to be a trigger that requires a response action, approval holders are required to continue to monitor temperature and other physical parameters. Changes in temperature could be considered to be an early indicator that concentrations of chemical parameters may change. When increasing temperatures are observed approval holders may increase their monitoring frequency to capture the early mobilization of constituents.

4.2.3 Management Response at the Point of Management

The approval holder shall implement the following site-specific management response after confirmation of Trigger 2:

- Submit notification letter within 30 days.
- Maintain or increase the frequency of sampling for indicator and physical parameters to a quarterly basis at a minimum at the Point of Management.
- May decrease the frequency of sampling for all parameters to an annual basis at a minimum at the Heat Source.
- Within twelve (12) months of confirming Trigger 2 in an AMU, install monitoring well(s) at the Point of Compliance into the affected AMUs.
- Submit the following information to the Director as part of their next regularly submitted Groundwater Monitoring Report:
    - Maximum concentrations observed to date at the Heat Source. The approval holder shall indicate whether or not these concentrations represents a peak value or if concentrations observed at the Heat Source are continuing to increase;
    - A comparison between the concentrations of indicator parameters at the Heat Source and the Point of Management to determine plume velocity and attenuation;
    - Predicted extent of thermal plume and chemical plumes for indicator parameters;
    - Point of Compliance location, respecting the criteria provided in Section 1.5;
    - Predicted maximum temperature at the Point of Management;
    - Predicted maximum concentrations for indicator parameters at the Point of Management;
    - Predicted time of arrival of chemical plumes for indicator parameters at the Point of Compliance, when known;
    - Predicted maximum concentrations of indicator parameters at the Point of Compliance, when known;
    - Proposed modelling approach to be used for long term monitoring; and,

- Groundwater Management Response Plan.

4.3 Point of Compliance

4.3.1 Monitoring Requirements at the Point of Compliance

Approval holders shall install monitoring wells in the AMUs at the Point of Compliance following the criteria outlined in Section 1.5 and shall establish baseline conditions. Baseline sampling should be established by using samples taken at a quarterly frequency to ensure that seasonal influences are accounted for. More frequent samples may be taken but should not be used to establish baseline in a short period of time. The position of the monitoring well(s) and sampling frequency at the Point of Management shall be such that the entire baseline data set shall be collected prior to any effects reaching and influencing the monitoring well. Baseline conditions are to be determined using an appropriate statistical method once sufficient data is collected.

Once baseline is determined for each monitoring well at the Point of Compliance, the approval holder shall continue to monitor both indicator parameters and physical parameters on an annual basis at a minimum.

4.3.2 Triggers at the Point of Compliance

The following site-specific triggers are to be set at the Point of Compliance:

Trigger 3:

- Change in concentration of an indicator parameter from baseline that indicates an increasing trend at a Point of Compliance well

Although a change in temperature is not considered to be a trigger that requires a response action, approval holders are required to continue to monitor temperature. Changes in temperature could be considered to be an early indicator that concentrations of chemical parameters may change. When increasing temperatures are observed approval holders may increase their monitoring frequency to capture the early mobilization of constituents.

4.3.3 Management Response at the Point of Compliance

The approval holder shall implement the following site-specific management response upon confirmation of Trigger 3:

- Report the release as an incident as outlined in Part 5 Sections 110, 111, and 112 of *EPEA;*
- Maintain or increase the frequency of sampling for indicator and physical parameters to a quarterly basis at a minimum at the Point of Compliance; and.
- Initiate the relevant actions described in Section 7 and those outlined in the site-specific Groundwater Management Response Plan.

5 Summary of Monitoring Requirements

Monitoring requirements detailed above are summarized in Table 1.

Table 1: Summary of Minimum Monitoring Requirements for Chemical Analysis

	Monitoring Location		
	Heat Source	**Point of Management (POM)**	**Point of Compliance (POC)**
Approximate Location	Downgradient of Heat Source (~20 m)	5 years of groundwater flow in the downgradient position	Between Heat Source and receptors or 1km downgradient of Heat Source
Timeline for Installation	Prior to steaming	Within 12 months of confirming Trigger 1	Within 12 months of confirming Trigger 2
Monitoring Frequency	Prior to Triggers 1 & 2: • 3 point of reference samples to be collected prior to steaming • Quarterly After Trigger 2: • Annually After Trigger 3: • Frequency outlined in response plan	After Trigger 1: • Quarterly until baseline established • Semi-annually after baseline is established After Trigger 2: • Quarterly After Trigger 3: • Frequency outlined in response plan	After Trigger 2: • Quarterly until baseline established • Annually after baseline is established After Trigger 3: • Quarterly
Parameters to Monitor	• Chemical and physical parameters	• Chemical and physical parameters until baseline established • Indicator and physical parameters until closure	• Chemical and physical parameters until baseline established • Indicator and physical parameters until closure

6 Methodology for Monitoring and Analysis

All monitoring well installation procedures, well development procedures, and well logs shall be submitted as part of the Project Assessment or Groundwater Monitoring Thermal Proposal or Groundwater Monitoring Thermal report or Groundwater Monitoring Report. All newly installed wells shall be drilled and constructed according to standard industry practice and any pertinent AER requirements and shall be appropriate for higher temperature situations. All sampling procedures shall be submitted as part of the Groundwater Monitoring Thermal Proposal or Groundwater Monitoring Report, and shall be subject to acceptance by the Director. Sampling shall be conducted according to standard industry practice to ensure proper well purging, sample collection, and sample integrity (physical and chemical) during transport to the laboratory. A Quality Assurance/Quality Control (QA/QC) shall be implemented for sample collection.

All samples shall be analyzed in a laboratory accredited pursuant to ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories.* Baseline data from all monitoring wells shall represent stable groundwater conditions; otherwise additional sampling shall be conducted.

All collected data shall be verified for accuracy. Verification including any necessary re-sampling should be completed after any triggers have been reached but prior to submitting 30-day notification letters. Verification sampling should be completed within the same quarterly timeframe as the original sample collection.

Statistical analysis of groundwater chemistry data shall be conducted. The goal of the statistical analysis is to characterize baseline data such that increasing trends and concentrations beyond baseline conditions can be determined. Once sufficient data are available to statistically characterize baseline groundwater quality, appropriate statistical methods may be used. Approval holders shall provide clear documentation of the type(s) of software used in the analysis, including version number(s) and relevant information on the software source and publisher. The use of nonstandard methodologies should be avoided.

7 Site-Specific Groundwater Management Response Plan

Approval holders shall submit a site-specific Groundwater Management Response Plan after confirming Trigger 2 at the Point of Management as a component of their next regularly submitted Groundwater Monitoring Report. The response plan shall outline the actions that the approval holder will implement to mitigate the effects of thermal mobilization at Point of Compliance. A component of the response plan could include a risk assessment of indicator parameter concentrations to receptor locations.

Possible actions that may be implemented after Trigger 3 is confirmed at the Point of Compliance include, but are not limited to:

- Additional modelling work to better describe effects and risk scenarios;
- Installation of additional monitoring wells to better delineate effects;
- Collection of additional field data to better characterize site conditions;
- Enhanced risk assessment, considering new monitoring, modelling and other information;
- Groundwater remediation;
- Reduction in scale or intensity of operations; or
- Termination of operations.

Approval holders shall implement the site-specific Groundwater Management Response Plan within six (6) months of confirming Trigger 3.

8 Closure Process

As part of the closure process, approval holders are required to submit a Reclamation Plan as outlined in the *Guide to Content for Energy Project Applications* which shall include a risk assessment and post-operations monitoring program after the termination of steam injection activities. The Reclamation Plan shall include all the work conducted (Heat Source monitoring, Point of Management monitoring, Point of Compliance monitoring) and shall consider the type, transport and fate characteristics of all indicator parameters. Monitoring by the approval holder shall continue after termination of steam injection activities to demonstrate to the Director that the groundwater conditions are following a simulated trajectory derived by modelling (i.e., within an acceptable tolerance of simulated versus measured readings). The Reclamation Plan shall include:

- Validated attenuation rates projected by the model.
- Identification of any indicator parameters that will migrate past the Point of Compliance.
- Risk assessment of indicator parameters that will migrate past the Point of Compliance.
- Predicted extent of thermal plume and chemical plumes for indicator parameters.

If prolonged monitoring indicates the stabilization of groundwater conditions at constituent concentrations above baseline values, the Director shall determine appropriate alternate closure conditions.

9 Submission Process

9.1 New Projects

Development and submission of the various components of the Project Assessment and Groundwater Monitoring Program to address potential thermal mobilization of constituents is integrated with the *EPEA* approval application process.

A project is considered to be new if an *EPEA* approval has not been issued before the Effective Date of this *Directive* (Section 1.2). The Project Assessment shall be submitted to the Director at the time of application for new projects.

After the Project Assessment has been submitted and accepted, the approval holder shall install groundwater monitoring wells near the Heat Source, in all aquifers identified as AMUs for long-term monitoring. AMUs shall be characterized to establish a point of reference and triggers established to determine if thermal mobilization of constituents is occurring. At this point, approval holders should have sufficient site-specific information and shall submit the Groundwater Monitoring Thermal Proposal.

Once thermal effects have been observed and mobilization of chemical parameters has been detected through monitoring activities (i.e. Trigger 1 is confirmed), the Director shall be notified within 30 days. Updated and new information shall be submitted as part of the regularly submitted Groundwater Monitoring Report to include the requirements of Section 4.

The approval holder shall install groundwater monitoring wells at the Point of Management within twelve (12) months of confirming Trigger 1. Baseline data points required for motioning wells at the Point of Management shall be collected prior to the detection of any effects at each of the monitoring well locations. The Director shall be notified within 30 days upon confirming Trigger 2 and a site-specific Groundwater Management Response Plan submitted.

The approval holder shall install groundwater monitoring wells at the Point of Compliance within twelve (12) months of confirming Trigger 2. Baseline data points required for monitoring wells at the Point of Compliance shall be collected prior to the detection of any effects at each of the monitoring well locations. Upon the confirmation of Trigger 3 at the Point of Compliance, approval holders shall report the release as outlined in Part 5 Sections 110, 111, and 112 of *EPEA* and shall implement the site-specific Groundwater Management Response Plan.

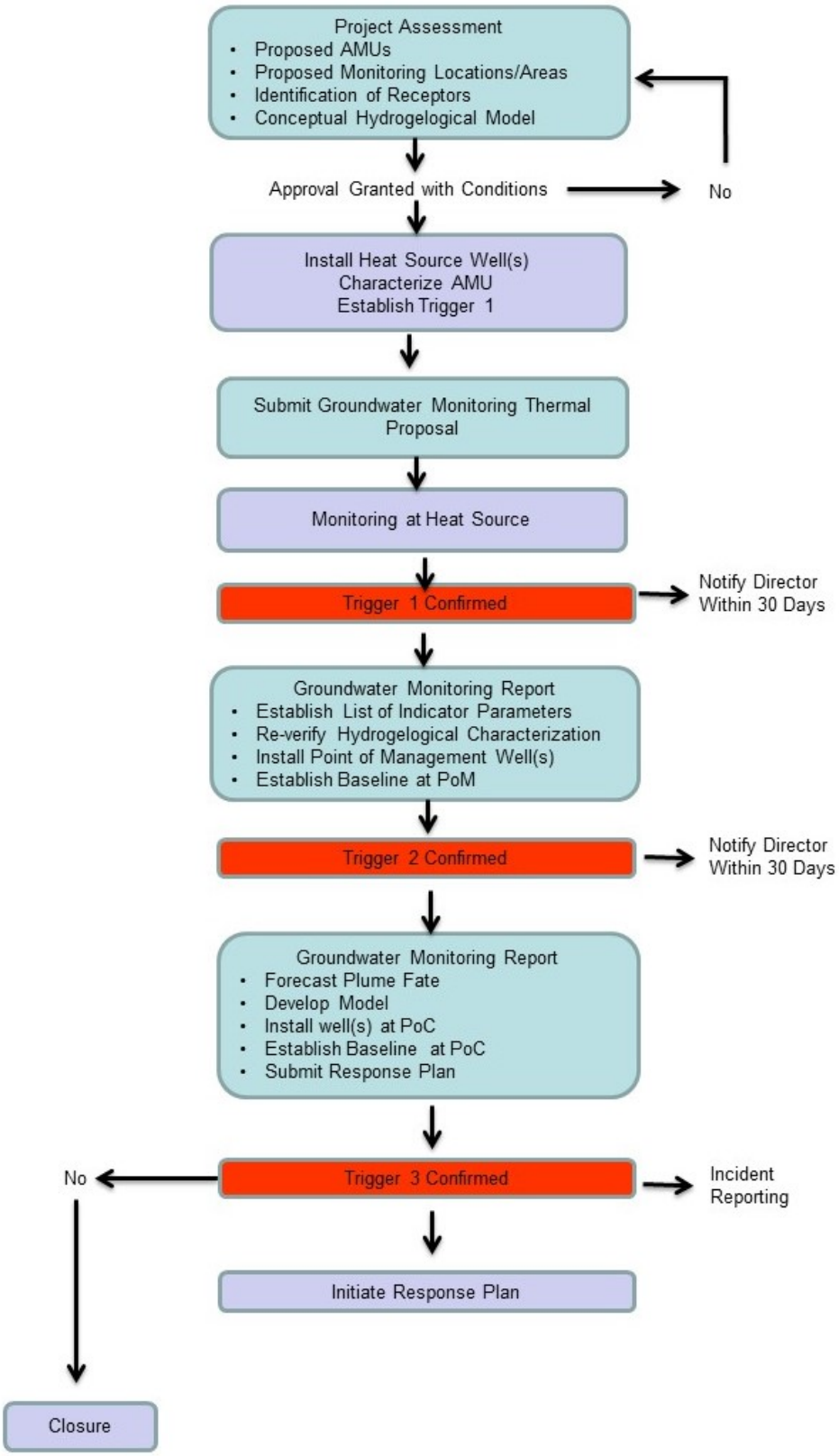

Figure 4: Submission Process for New Projects

9.2 Existing Projects

A project is considered to be an existing project if an *EPEA* approval has been issued before the Effective Date of this *Directive* (Section 1.2). Approval holders shall submit a Groundwater Monitoring Report titled "Groundwater Monitoring Thermal Report <EPEA Approval No.>" under a separate cover by March 31, 2020. Within the Groundwater Monitoring Thermal Report, approval holders shall submit the following required information:

- conceptual hydrogeologic model,
- identification of AMU(s);
- identification of receptors;
- baseline data at the Heat Source for each AMU based on historical or background monitoring wells if known;
- proposed location(s) of background monitoring wells for each AMU if needed;
- location(s) and construction details of the Heat Source monitoring well(s);
- timelines associated with additional monitoring well installations;
- proposed Management Area for each monitoring location with justification, as available;
- list of parameters;
- list of indicator parameters, if known;
- temperature profile(s) within the Heat Source monitoring well(s);
- description of proposed response action at the Heat Source;
- description of proposed monitoring activities and response actions at the Point of Management and Point of Compliance; and,
- Groundwater Monitoring Report submission frequency.

Approval holders shall install a Heat Source well by March 31, 2020 that is:

- Located within 50 m of the Heat Source
- Located down-gradient of the Heat Source
- Alternate distances and locations may be approved by the Director.

In addition, approval holders shall compare their existing monitoring program with requirements of this *Directive* and outline proposed actions to meet the requirements. Subsequent thermal monitoring under this *Directive* shall be included within the regularly submitted *EPEA* Groundwater Monitoring Report.

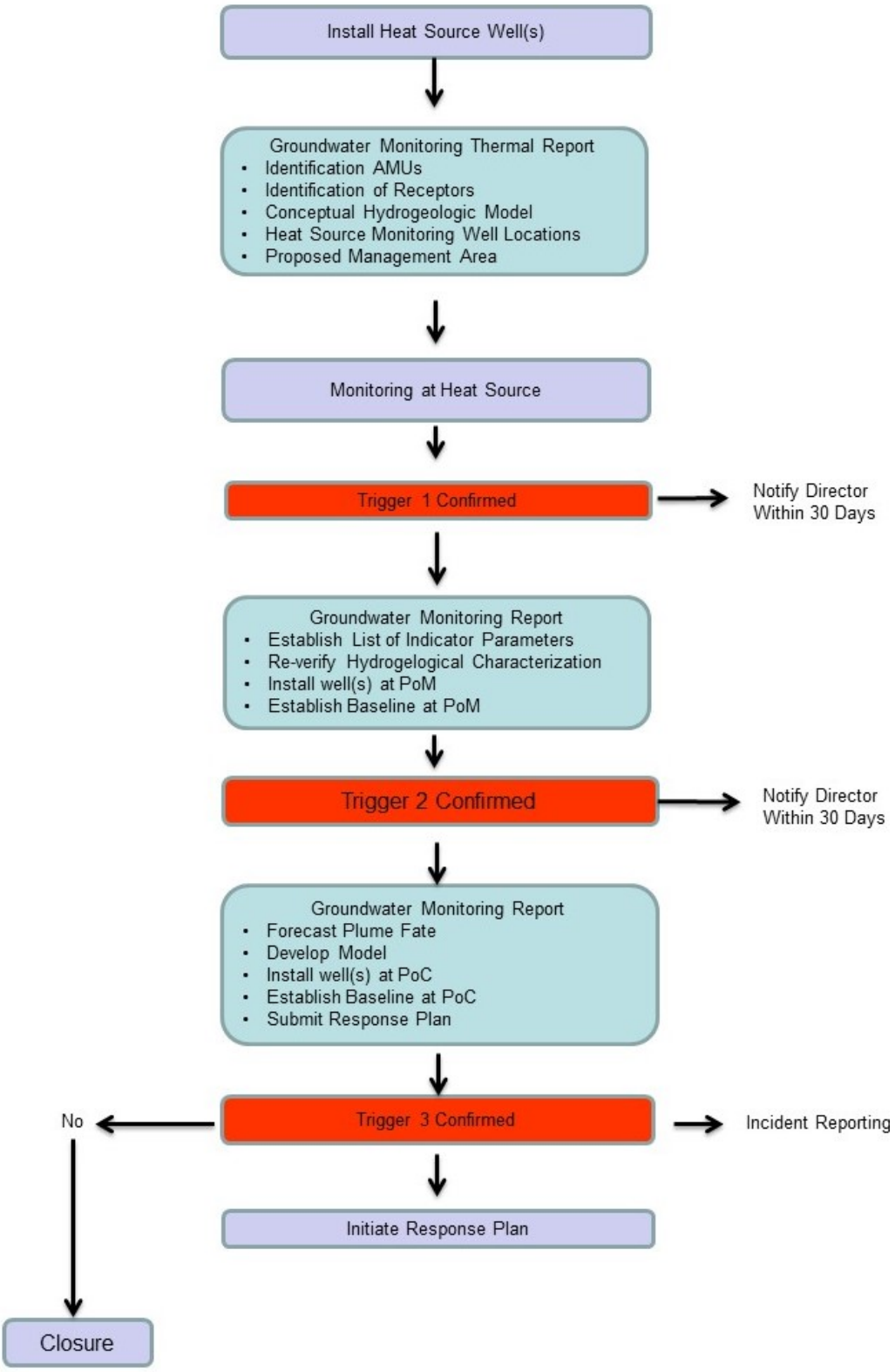

Figure 5: Submission Process for Existing Projects

Original signed by: Date: May 24, 2018

Karen Wronko, Executive Director
Water Policy
Environment and Parks