

POST PRODUCTION INSPECTION GUIDANCE

**City of Grand Prairie
Dallas, Tarrant, Johnson and Ellis Counties, Texas**

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Post Production Inspection Guidance

PURPOSE

The City of Grand Prairie (City) is located above the Barnett Shale Formation and within the Fort Worth Basin. The Barnett Shale is an unconventional natural gas reservoir that typically utilizes the installation of horizontal wells at depth followed by hydraulic fracturing to increase available natural gas flow to the wells. Responsible extraction of natural gas from this resource is anticipated to be a long-term part of the landscape in Grand Prairie and its Extra-Territorial Jurisdiction (ETJ). To assist in this process, the City developed Leak Detection and Control guidance to ensure that natural gas operations are performed in as protective a manner as possible for both operators and the surrounding community.

As gas production is completed and the former padsites containing wells, separators, aboveground storage tanks, and related infrastructure are plugged and/removed, there are specific redevelopment concerns that should be addressed by either the operator, property owner, and/or redeveloper.

The City has developed this guidance with the support of Modern Geosciences, LLC (Modern) to aid all parties as the property use transitions from natural gas production to new uses. In addition to City guidance, we recognize that the U.S. Environmental Protection Agency (EPA), Texas Department of State Health Services (DSHS), Texas Commission on Environmental Quality (TCEQ) and Texas Railroad Commission (RRC) can have regulatory authority over specific elements of the padsite decommissioning process or proposed redevelopment.

Disclaimer

The City of Grand Prairie has provided this document as guidance only. All affected parties will need to determine the appropriate level of assessment or mitigation needed to meet final redevelopment goals. This should include project-specific communication with the City of Grand Prairie as needed. Additional guidance can be obtained from the Texas Railroad Commission, Texas Department of State Health Services, Texas Commission on Environmental Quality, and U.S. Environmental Protection Agency. Mention of specific equipment within this document does not imply an endorsement.

ACRONYMS

A listing of common acronyms associated with monitoring activities has been provided to aid the guidance material. Additional acronyms may be defined within the text as well.

API	American Petroleum Institute
AST	Aboveground storage tank
ASTM	ASTM International
BACT	Best Available Control Technology
BBL	Barrel
BMP	Best Management Practice
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
CESQG	Conditionally Exempt Small Quantity Generator
CO ₂	Carbon Dioxide
COC	Chemicals of Concern
DSHS	Texas Department of State Health Services
EPA	United States Environmental Protection Agency
ESL	Effect Screening Level (Short- or Long-Term Criteria)
ETJ	Extra Territorial Jurisdiction
FID	Flame Ionization Detector
FRP	Fiberglass Reinforced Plastic
GHG	Greenhouse Gas
H ₂ S	Hydrogen Sulfide
HAP	Hazardous Air Pollutant
HASP	Health and Safety Plan
HQ	Hazard Quotient
IDLH	Immediately Dangerous to Life and Health
IHW	TCEQ Industrial & Hazardous Waste Program
LDAR	Leak Detection and Repair
LDCP	Leak Detection and Compliance Plan
MACT	Maximum Achievable Control Technology
Mcf	Thousand Cubic Feet
MSDS	Material Safety Data Sheet
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NORM	(Technologically Enhanced) Naturally Occurring Radioactive Material
NSPS	New Source Performance Standards
OGI	Optical Gas Imaging
OSHA	Occupational Safety & Health Administration
PEL	OSHA Permissible Exposure Limit

PID	Photo Ionization Detector
PTE	Potential to Emit
RACT	Reasonably Available Control Technology
RBEL	Risk Based Exposure Limit
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
REC	Reduced Emission Completion
ROD	Record of Decision
RRC	Texas Railroad Commission
Scf	Standard Cubic Feet
Scf/h	Standard Cubic Feet per hour
SVOCs	Semi-volatile Organic Compounds
TCEQ	Texas Commission on Environmental Quality
TOX	Total Organic Halides
TPH	Total Petroleum Hydrocarbons
TPWD	Texas Parks and Wildlife Department
TRRP	Texas Risk Reduction Program
TWDB	Texas Water Development Board
TXU	Texas Utilities
URF	Unit Risk Factor
USC	United States Code
USGS	United States Geological Survey
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
VRU	Vapor Recovery Units

1 REGULATORY BACKGROUND

This section offers a brief overview of the current regulatory environment concerning the transition of a natural gas padsite to other unrestricted uses.

1.1 MIXED TRANSITIONAL RULES

As oil and/or natural gas padsites are decommissioned and future development contemplated, it is important that final site conditions be evaluated to confirm if potential hazards to an intended reuse are present. While multiple regulations from the RRC apply during drilling, hydraulic fracturing, and production, there is no guidance from the RRC specifically focused on a transition to general reuse. Further, since many regulatory elements of the TCEQ, RRC, and DSHS are not consistent given the unique areas they govern, it is possible for conditions at a former padsite to be a potential concern to reuse despite having properly addressed other regulatory compliance needs. This may be best exemplified by a Texas Radiation Advisory Board (TRAB) letter dated February 10, 2003 which provided comment on RRC rules that are now in effect. Concerns that the TRAB noted include a lack of reporting to RRC when radiation criteria are exceeded, a lack of communication to the landowner when elevated radiation will remain after padsite decommissioning, and inconsistency in DSHS versus RRC criteria (a six-fold difference). The TRAB noted “allowing land application of NORM without notification and consent of the landowner and subsequent landowners is a trial lawyer’s dream come true.” For reference, Modern’s experience in the Barnett Shale has included padsite equipment exhibiting NORM in excess of 1,300 $\mu\text{R/hr}$ (more than twice the highest level reported by the RRC within a 2000 study of over 600 leases).

It is the responsibility of any party controlling or directing reuse to ensure all applicable regulations have been met.

1.2 GRAND PRAIRIE ORDINANCE REQUIREMENTS

Chapter 13, Article XIX, Section 13-500 of the Grand Prairie Code of Ordinances provides for the following at the end of a padsite’s operations:

Key terms (Sec. 13-501) that inform compliance expectations:

- *Abandonment* means "abandonment" as defined by the commission and includes the plugging of the well and the restoration of any well site as required by this article.
- *Contaminant* means any substance capable of causing pollution, including but not limited to smoke, vapors, fumes, acids, alkalis, toxic chemicals, liquids, or gases, drilling fluids including muds, or other irritants.
- *Landfarm* means the depositing, spreading or mixing of drill cuttings, drilling fluids, drilling mud, produced water or other drilling waste generated by natural gas drilling process onto the ground.
- *Padsite* means the area that is fenced and constructed to contain all drilling related activities, including, but not limited to the drilling rig, pipe rack, generators, pumps, compressors, frac tanks, camper/office trailers, tank batteries, separators, dehydrators, metering stations, equipment storage, and living quarters.
- *Padsite boundary* means the perimeter boundary of the pad site as defined in this article. Pad site boundaries shall be described by a metes and bounds survey included in the gas well permit application. A screening fence is required to be construction along the pad site boundaries.
- *Person* means both the singular and the plural and means a natural person, a corporation, association, guardian, partnership, receiver, trustee, administrator, executor, and fiduciary or representative of any kind.

Section 13-518 (Plugged and Abandoned Wells) requires:

- Whenever abandonment occurs pursuant to the requirements of the commission, the operator so abandoning shall be responsible for the restoration of the well site to its original condition as nearly as practicable.
- All waste, refuse or waste material shall be removed from the drill site.

- A permanent abandonment marker pipe, with the well identity and location permanently inscribed, shall be welded to the casing and shall be at least four (4) inches in diameter with a length of four (4) feet visible above the ground level.
- The operator shall furnish the following at the discretion of the inspector when abandoning a well:
 - A copy of the approval of the commission (RRC) confirming compliance with all abandonment proceedings under the state law; and
 - A notice of intention to abandon under the provisions of this section and stating the date such work will be commenced. Abandonment may then be commenced on or subsequent to the date so stated.
- *Abandonment requirements prior to new construction.* All abandoned or deserted wells or drill sites shall meet the most current abandonment requirements of the commission (RRC) prior to the issuance of any building permit for development of the property. No structure shall be built over an abandoned well.

1.3 OTHER RULES THAT MAY APPLY

Since project-specific elements can dictate what rules may apply it is important to keep some of the following in mind as redevelopment planning is being completed. One or more may apply:

- TCEQ generally governs impact meeting a “release” and/or “discharge” as defined by statute (Texas Health and Safety Code §361.003 and the Texas Water Code §26.001 and §26.121) and in rule (30 TAC 334.7, 335.1, and 350.4).
- RRC Statewide Rule 14 (§3.14(8)) requires that “a 10-foot cement plug shall be placed in the top of the well, and casing shall be cut off three feet below the ground surface.” Other RRC rules would apply if continued operation of a padiste is anticipated.

- Texas Parks and Wildlife is authorized to address impact affecting aquatic life and wildlife per Texas Water Code §26.124(b).
- DSHS is authorized to address the abatement of nuisances resulting from pollution not otherwise covered by Texas Water Code or Texas Health and Safety Code.

2 INTERIM PPI INSPECTION (PRIOR TO WELL PLUGGING)

2.1 LEGACY ENVIRONMENTAL CONCERNS

As discussed earlier, the nature of environmental regulations often requires the criteria applied be specific to a given use. In this case, the final compliance thresholds for the RRC, which are focused on resource extraction and not redevelopment, can leave impacts that may not be appropriate for a future unrestricted (i.e., residential) use. While this should be a consideration in any environmental due diligence process by a prospective redevelopment team, the recent occurrence of natural gas exploration and production within the urban environment may be unfamiliar to many consultants. The City developed this guidance to aid all parties as they complete padsite decommissioning and/or their environmental due diligence process.

Common future use concerns should include a consideration for future subgrade leaks if residual gathering lines are present, elevated radiation from technologically enhanced naturally occurring radioactive material (NORM)-containing scale, and/or other unidentified spills or releases that have not been properly evaluated.

While no level of investigation can completely remove all risk at a given property, the City worked with Modern to leverage their extensive experience in this area to develop some basic post-production inspection (PPI) best practices to consider. Conceptually this is best performed in two steps. An interim PPI event just prior to equipment removal and well plugging followed by a final PPI event to confirm the final conditions of the padsite at the end of all oil and gas activities.

Note: An additional benefit to performing an interim PPI event on a padsite is the consolidation of final RRC documentation and field inspection results together in a format that can be referenced by future parties considering redevelopment. This can be of vital importance in future environmental due diligence and save time and resources. The interim event is best performed prior to equipment removal.

2.2 INTERIM PPI EFFORT

When possible, it is preferred to bridge any production inspection programs with the post-production evaluation effort. This will allow the inclusion of any past concerns (e.g., NORM-containing equipment, record of spills, leaks, or other issues unique to the padsite). An interim inspection should occur whenever the operator has plans to plug an existing well. The City of Grand Prairie currently includes a requirement for the operator to provide notice of the intent to abandon wells under Sec. 13-518(c). A copy of the Form W-3A (Notice of Intention to Plug and Abandon) as submitted to the RRC should be included within the Interim PPI report.

Since the purpose of the PPI is to screen for potential environmental risk to future uses and may include sampling and the generation of new geoscientific data, a Texas-licensed Professional Geoscientist (PG) or Professional Engineer (PE) should be engaged to complete the following. Additionally, any investigation effort should only be performed if proper health and safety planning has been performed.

- **Step 1: Infrastructure Verification:** Record all existing and prior infrastructure locations at the padsite using GPS equipment with an accuracy of 24" or less and develop representative figure(s). Record the latitude and longitude coordinates for all wells, separators, compressors, and aboveground storage tanks to at least a six-digit resolution. If subgrade piping is present, make note of where this is likely located so future inspections can be informed by this. Keep in mind that some padsites will have off-site infrastructure related to other production equipment and may leave subgrade components in place and otherwise undocumented. It is recommended that the location of this subgrade piping also be noted up to 250 feet off the padsite boundary. It is preferred that a GIS shapefile also be provided for City use in the future.
- **Step 2: Compliance Records Review:** Review all prior inspection reports concerning leaks, spills, releases, or other record of non-compliance to inform future field screening efforts once equipment is removed. Emphasis should be placed on confirming any elevated NORM observations, prior spills or releases, or poor operator maintenance records suggestive of problem areas to include in any future inspections.

- **Step 3: Compliance Inspection:** Complete a physical inspection of the current operational state of the padsite relative to City ordinance requirements.

- **Step 4: Surface Inspection:** Complete a surface inspection for the presence of visual evidence of a release or NORM immediately near all static equipment and within all secondary containment. This should include:
 - a) Visual inspection of all equipment and operational areas for suggestion of spills/releases, or other concerns that should be addressed by the operator;

 - b) Collection of a background radiation reading at least 250 feet away from the nearest padsite boundary and/or above grade equipment or assume 10 μ R/hr (general background);

 - c) Collection of radiation data using meters consistent with 16 TAC §4.605(d)/25 TAC §289.259(e), on an approximate 10' x 10' grid in all applicable areas, including within secondary containment;

 - d) Note all current radiation readings at each piece of equipment and, if applicable, that signage per 16 TAC §4.603(7) is present;

 - e) Note all areas exceeding site-specific NORM screening criteria (i.e. twice background); and

 - f) Note any remnant equipment or piping staged at the padsite that could be indicative of containing elevated NORM. Collect representative radiation readings as appropriate for all areas.

- **Step 5: Reporting:** A summary report should be prepared documenting all the above items are completed with a summary of all screening results. The report should include infrastructure locations, a compliance summary, field screening results, equipment used to include calibration and resolution data, a figure depicting the padsite, photos, and laboratory data (if applicable). Any results should be compared to applicable RRC, TCEQ, and/or DSHS regulations. If exceedances are noted, the operator and/or landowner should be contacted to determine if additional corrective action is needed.

The result of any interim PPI should be communicated to the operator to allow them the opportunity to address concerns during the padsite decommissioning process.

3 FINAL PPI INSPECTION (ALL INFRASTRUCTURE REMOVED)

When all wells and related infrastructure have been properly plugged according to current RRC rules (i.e. RRC SWR 14), all production equipment and piping removed, the following is recommended for completion by a Texas-licensed PG or PE. Additionally, a copy of Form W-3 (Plugging Record) should be included within the PPI report.

3.1 FINAL PPI EFFORT

The PPI effort should include the following steps:

- **Step 1: Infrastructure and Compliance Summary:** Completion of Steps 1 through 3 outlined in the Interim PPI effort – if not previously addressed;
- **Step 2: Plugging Records Review:** A review of all submitted RRC plugging documents should be made to ensure all required steps have been completed. These documents should be included with the final report;
- **Step 3: Surface Inspection:** The inspector should prepare a 10' by 10' grid of all areas of the padsite historically associated with production infrastructure to allow surface screening for potential concerns. At a minimum, grids should extend at least 10 feet beyond prior subgrade and abovegrade infrastructure. Once the grid is marked off in the field, screening should include an evaluation of background at least 250 feet away from the nearest padsite boundary and/or above grade equipment with any survey instrument and at least one inspection point per grid for the following:
 - a) Visual Evidence of Releases: An evaluation of each grid should be made to determine if visible evidence of a release or odors are present. This can include dark staining, sheens, or other observations suggestive of remnant impact on the padsite. If visual evidence of a release is noted, the impact should be documented with a perceived area of highest impact confirmed and a surface soil sample collected. *See suggested analysis in Appendix A.*

- b) Methane: Using calibrated equipment capable of detecting methane to 1 ppmv, screen within 2” or less above the surface in each grid. If methane is noted above 10 ppmv or 2x background, inspection should be continued until the highest observation is verified and marked to allow further evaluation of possible subgrade leaks. The operator, landowner and City should be contacted if elevated methane is identified so the source can be identified and addressed. If methane above 10,000 ppmv (1% by volume), this should be immediately reported to the City Fire Department for further evaluation of possible explosive environments remaining on site.
- c) VOCs: Using a PID capable of detecting total VOCs (tVOCs) to 1 ppbv, screen each grid by removing approximately three (3) inches of surface soil from the selected point in each grid and cup your hand to prevent dilution with ambient air. If tVOCs are noted above 100 ppbv (0.1 ppmv) or 10x background, inspection should be continued until the highest observation is verified and marked to allow collection of a surface soil sample. See *suggested analysis in Appendix A*.
- d) Corrosivity (pH): Using a pH meter capable of measuring to 0.1 standard units (s.u.), screen surface soil by inserting the probe approximately three (3) inches in the ground in each grid to confirm the representative pH. If pH is noted outside a typical background range (e.g., 5 to 9.5 s.u.) or within 25% of the background reading collected, inspection should be continued until the highest/lowest readings outside normal is identified to allow collection of a surface soil sample. See *suggested analysis in Appendix A*.
- e) Radiation: Using a radiation meter consistent with 16 TAC §4.605(d) and 25 TAC §289.259(e), screen immediately above the existing surface of all grids (no more than 2” above). If a grid exhibits a concentration more than 2x background, inspection should be continued until the highest observation is verified and marked to allow collection of a surface soil sample and further evaluation to determine if buried NORM-containing equipment is present. See *suggested analysis in Appendix A and suggested radionuclides that need to be evaluated in Appendix B*. If collecting a surface soil sample for analysis, an off-site sample must be collected for background comparison purposes.

All grids exhibiting radiation in excess of 2x background should also be evaluated using a calibrated alpha ionization detector (AID) with a detection limit of <0.1 pCi/L to screen for a combined ^{220}Rn and ^{222}Rn value since these portions of the expected decay series are radioactive gases.

- **Step 4: Site-wide Subgrade Leak Evaluation:** If the padsite previously included subsurface piping or related gathering lines at the padsite or up to 250 feet away the padsite boundary, screening with an optical gas imaging (OGI) camera should be performed across the padsite and at least 250' from all areas where subgrade piping is suspected or known. If any OGI visual evidence of a leak is identified, this should be marked and immediately brought to the attention of the landowner, operator, and City for additional corrective action.

Note: It is highly recommended that any remnant subgrade piping from the prior operations be removed to minimize future concerns. If subgrade piping will remain in place, the operator should consult with the City to ensure the City is aware of the subgrade piping locations. Any remaining lines should be flushed and have integrity confirmed prior to continued use. Future integrity evaluations should be considered if continued use is anticipated as many gathering lines are not otherwise monitored by regulatory entities.

- **Step 5: Reporting:** A summary report should be prepared documenting all the above items are completed with a summary of all screening results and any sampling results. The report should include infrastructure locations, a compliance summary, field screening results, equipment used to include calibration and resolution data, a figure depicting the padsite, photos, and laboratory data (if applicable). Any soil sampling results should be compared to applicable RRC, TCEQ, and/or DSHS regulations. If exceedances are noted, the operator and landowner should be contacted to determine if additional corrective action is needed. If final conditions are anticipated to exceed applicable regulatory criteria, the results should be forwarded to the applicable regulatory agency for review and further direction.

3.2 SELECTED COMPLIANCE NOTES

The following are common compliance elements that should be considered in any PPI or redevelopment effort.

- In order to protect public health and safety and the environment, the RRC requires the owner or operator of oil and gas equipment to determine whether the equipment contains or is contaminated with NORM waste. Citation: 16 TAC §4.635(c)(1);
- NORM-contaminated equipment is defined as “equipment that, at any accessible point, exhibits a minimum radiation exposure level greater than 50 μ R/hr including background radiation level.” Citation: 16 TAC §4.603(7);
- Owner or operators shall identify NORM-contaminated equipment with the letters "NORM" by securely attaching a clearly visible waterproof tag or marking with a legible waterproof paint or ink. Citation: 16 TAC §4.605(a)'
- Disposal of oil and gas NORM waste by spreading on public or private roads is prohibited. Citation: 16 TAC §4.611;
- Burial of NORM-contaminated equipment is prohibited. Citation: 16 TAC §4.614(c);
- A person may “dispose of oil and gas NORM waste at the same site where the oil and gas NORM waste was generated by applying it to and mixing it with the land surface, provided that after such application and mixing the radioactivity concentration in the area where the oil and gas NORM waste was applied and mixed does not exceed 30 pCi/g Radium-226 combined with Radium-228 or 150 pCi/g of any other radionuclide.” Citation: 16 TAC §4.614 (c)&(d). It should be noted that laboratory analysis is required to determine concentrations of individual radioisotopes. Additionally, the current unrestricted criteria for selected radioisotopes may differ should the site use change. For example, 30 TAC 336.356 (Standards for Protection Against Radon) sets an individual maximum for radium-226 or radium-228 at 5 picocuries/gram (pCi/g), averaged over the first 15 centimeters of soil below the surface. Consultation with the landowner is

suggested if an exceedance of this criteria is anticipated so this information can be incorporated into future redevelopment planning;

- Decontamination of NORM-contaminated equipment requires a license from the Texas Department of State Health Services pursuant to 25 TAC 289.259(i). Citation: 4.632(d)(6) & (7); and
- In addition to State requirements, the City ordinance specifies other post-production requirements under Section 13-518 (Plugged and Abandoned Wells). This includes requirements for signage and prohibitions of use above/adjacent to plugged wells. A permanent abandonment marker pipe, with the well identity and location permanently inscribed, shall be welded to the casing and shall be at least four (4) inches in diameter with a length of four (4) feet visible above the ground level. Please refer to the current ordinance requirements for the specific requirements of a surface reclamation plan.

Redevelopment Note: When former gas wells are abandoned pursuant to RRC rules, there can be little evidence in the field of the plugged well found above grade without the signage requirements outlined in the City's ordinance. Since property boundaries as well as site uses can change over time, the City's goal in signage over all plugged wells is to ensure all future parties have full knowledge of legacy subgrade infrastructure. However, in an effort to not prohibit future development when it serves the community interests, we understand a balance of understanding risk versus mitigation through development is desirable. To that end, this guidance document offers suggested approaches to evaluating legacy risk.

Prior to the development of this guidance document, many redevelopment projects did not incorporate even the most basic screening efforts to confirm if legacy contamination would be a concern to their future uses.

If a redevelopment contemplates the reuse of any part of a former padsite, we strongly suggest the performance of PPI as outlined in this document. Keep in mind that the identification of surficial concerns may necessitate the further evaluation of subsurface conditions in soil, soilgas, or groundwater. This is beyond the initial screening effort outlined in this guidance.

APPENDIX A
Analysis Table

Concern	Soil Analysis
Visual evidence of a release	TPH by TCEQ Method TX1005/EPA 5035A VOCs by EPA Method SW-846 8260/5035A RCRA 8 Metals by EPA Methods SW-846 6010/6020/7471/7470 Corrosivity (pH) by EPA Method SW-846 9045/4500 Chlorides by EPA Method 300
tVOCs >0.01 ppmv to 0.1 ppmv	TPH by TCEQ Method TX1005/EPA 5035A VOCs by EPA Method 8260/5035A Chlorides by EPA Method 300
Corrosivity (pH) <5 or >9.5 s.u	Corrosivity (pH) by EPA Method SW-846 9045/4500 Chlorides by EPA Method 300 RCRA 8 Metals by EPA Methods SW-846 6010/6020/7471/7470
Radiation >2x Background (or 20 uR/hr)	Chlorides by EPA Method 300 Corrosivity (pH) by EPA Method SW-846 9045/4500 Gamma Spectroscopy NORM/TENORM Compounds by DOE HASL 300/GA-01R/901.1, ASTM D3972, and/or LANL ER200M for the common radionuclides noted below and targeted Alpha Spectroscopy by EPA 900 for Po-210. Must include Target Radionuclides noted in Appendix B at a minimum (related to the ²³⁸ U and ²³² Th decay series). Note: Provide activity in pCi/g

Notes on sample collection:

If extensive impact is present over multiple 10' by 10' grids from a common release, representation using the highest observed screening result over no more than a 500 ft² contiguous area can be used in lieu of sampling every grid.

If there is a regulatory exceedance identified from this screening and soil sampling event, further evaluation of groundwater may be warranted. Professional judgement by a licensed PG or PE will be needed to update the final sampling design once regulatory exceedances are confirmed.

APPENDIX B

Common Radionuclide List

Common Radionuclide List		
**Actinium 228	Europium 152	Radium 223
Americium 241	Europium 154	**Radium 224
Antimony 124	Europium 155	**Radium 226
Antimony 125	Iodine 131	**Radium 228
Barium 133	Iridium 192	Ruthenium 106
Barium 140	Iron 59	Silver 110
Beryllium 7	**Lead 210	Sodium 22
**Bismuth 212	**Lead 212	**Thallium 208
**Bismuth 214	**Lead 214	**Thorium 234
Cerium 139	Manganese 54	Tin 113
Cerium 141	Mercury 203	Uranium 235
Cerium 144	Neptunium 239	**Uranium 238
Cesium 134	Niobium 94	Yttrium 88
Cesium 137	Niobium95	Zinc 65
Chromium 51	**Potassium 40	Zirconium 95
Cobalt 57	Promethium 144	
Cobalt 58	Promethium 146	
Cobalt 60	**Polonium 210 (Alpha Emitter)	** = Target Radionuclide