# Fish Passage Plan (FPP) Change Form

**Change Form # & Title**: 21IHR005 – Unit 4 Operating Range

**Date Submitted**: June 7, 2021

**Project**: Ice Harbor Dam

**Requester Name, Agency**: Lisa Wright, Corps

**Final Action:**

**FPP Section**: Table IHR-5 – Turbine Unit Operating Ranges.

**Justification for Change**:

This Change Form adds the official 1% operating range values for Unit 4 with hydraulically locked blades based on index testing performed in February 2021.

**Proposed Change**:

See next page.

**Comments**:

**Record of Final Action**:

Proposed Change:

Add Unit 4 range to Table IHR-5 – see next page in red text:

Table IHR-5. Ice Harbor Dam Turbine Unit Power (MW) and Flow (cfs) at ±1% of Peak Turbine Efficiency (Lower and Upper Limits of 1% Range) and Operating Limits. a

|  |  |  |
| --- | --- | --- |
| **Project**  | **IHR Unit 1 – with STS** | **IHR Unit 1 – No STS** |
| **Head** | **1% Lower Limit** | **1% Upper Limit**  | **Operating Limit b** | **1% Lower Limit** | **1% Upper Limit**  | **Operating Limit b** |
| **(feet)** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** |
| 85 | 51.7 | 8,417 | 83.6 | 13,590 | 92.8 | 16,053 | 51.9 | 8,340 | 89.9 | 14,452 | 102.6 | 16,859 |
| 86 | 52.6 | 8,443 | 84.6 | 13,585 | 94.3 | 16,077 | 52.7 | 8,367 | 91.0 | 14,447 | 103.1 | 16,715 |
| 87 | 53.4 | 8,469 | 85.6 | 13,580 | 95.7 | 16,099 | 53.5 | 8,392 | 92.0 | 14,441 | 103.6 | 16,568 |
| 88 | 54.2 | 8,494 | 86.6 | 13,574 | 97.3 | 16,144 | 54.3 | 8,417 | 93.1 | 14,436 | 104.1 | 16,420 |
| 89 | 55.0 | 8,518 | 87.6 | 13,569 | 99.0 | 16,187 | 55.1 | 8,441 | 94.2 | 14,430 | 104.5 | 16,252 |
| 90 | 55.8 | 8,542 | 88.6 | 13,563 | 100.1 | 16,158 | 55.9 | 8,465 | 95.3 | 14,424 | 104.5 | 16,034 |
| 91 | 56.5 | 8,548 | 89.8 | 13,585 | 101.0 | 16,058 | 56.6 | 8,471 | 96.5 | 14,448 | 104.5 | 15,822 |
| 92 | 57.1 | 8,554 | 90.9 | 13,607 | 101.9 | 15,960 | 57.3 | 8,477 | 97.8 | 14,471 | 104.5 | 15,614 |
| 93 | 57.8 | 8,559 | 92.1 | 13,628 | 102.8 | 15,864 | 58.0 | 8,482 | 99.0 | 14,494 | 104.5 | 15,411 |
| 94 | 58.5 | 8,565 | 93.2 | 13,649 | 103.6 | 15,769 | 58.6 | 8,488 | 100.3 | 14,516 | 104.5 | 15,213 |
| 95 | 59.2 | 8,570 | 94.4 | 13,669 | 104.5 | 15,675 | 59.3 | 8,493 | 101.5 | 14,537 | 104.5 | 15,019 |
| 96 | 59.9 | 8,589 | 95.3 | 13,662 | 104.5 | 15,425 | 60.1 | 8,511 | 102.5 | 14,530 | 104.5 | 14,845 |
| 97 | 60.7 | 8,607 | 96.3 | 13,655 | 104.5 | 15,180 | 60.8 | 8,529 | 103.6 | 14,522 | 104.5 | 14,676 |
| 98 | 61.5 | 8,624 | 97.3 | 13,648 | 104.5 | 14,941 | 61.6 | 8,546 | 104.6 | 14,515 | 104.5 | 14,509 |
| 99 | 62.2 | 8,641 | 98.2 | 13,641 | 104.5 | 14,708 | 62.4 | 8,563 | 105.7 | 14,508 | 104.5 | 14,347 |
| 100 | 63.0 | 8,658 | 99.2 | 13,634 | 104.5 | 14,481 | 63.1 | 8,580 | 106.7 | 14,500 | 104.5 | 14,187 |
| 101 | 64.0 | 8,707 | 99.9 | 13,590 | 104.5 | 14,318 | 64.1 | 8,629 | 107.4 | 14,454 | 104.5 | 14,037 |
| 102 | 65.0 | 8,756 | 100.6 | 13,547 | 104.5 | 14,158 | 65.2 | 8,677 | 108.2 | 14,408 | 104.5 | 13,890 |
| 103 | 66.0 | 8,804 | 101.3 | 13,505 | 104.5 | 14,001 | 66.2 | 8,725 | 108.9 | 14,363 | 104.5 | 13,746 |
| 104 | 67.0 | 8,850 | 102.0 | 13,463 | 104.5 | 13,847 | 67.2 | 8,771 | 109.7 | 14,319 | 104.5 | 13,605 |
| 105 | 68.0 | 8,896 | 102.6 | 13,422 | 104.5 | 13,697 | 68.2 | 8,816 | 110.4 | 14,275 | 104.5 | 13,466 |
|  | **IHR Unit 2 c – with STS** | **IHR Unit 2 c – No STS** |
| 85 | 77.0 | 12,134 | 86.8 | 13,678 | 89.4 | 14,254 | 78.2 | 12,244 | 89.2 | 13,967 | 91.2 | 14,392 |
| 86 | 77.9 | 12,112 | 88.1 | 13,698 | 90.8 | 14,290 | 79.2 | 12,241 | 90.5 | 13,987 | 92.7 | 14,389 |
| 87 | 79.3 | 12,166 | 89.1 | 13,670 | 92.2 | 14,333 | 80.9 | 12,344 | 91.9 | 14,022 | 94.2 | 14,509 |
| 88 | 80.2 | 12,143 | 90.4 | 13,687 | 93.6 | 14,363 | 81.9 | 12,338 | 93.2 | 14,041 | 95.6 | 14,511 |
| 89 | 81.6 | 12,194 | 91.1 | 13,614 | 95.0 | 14,474 | 83.2 | 12,377 | 94.5 | 14,058 | 97.1 | 14,500 |
| 90 | 82.5 | 12,170 | 92.4 | 13,631 | 96.4 | 14,508 | 84.2 | 12,371 | 95.9 | 14,090 | 98.6 | 14,619 |
| 91 | 83.9 | 12,230 | 93.7 | 13,659 | 97.8 | 14,526 | 85.5 | 12,408 | 96.9 | 14,062 | 100.1 | 14,643 |
| 92 | 84.8 | 12,216 | 95.0 | 13,686 | 99.2 | 14,536 | 86.9 | 12,458 | 97.5 | 13,977 | 101.5 | 14,762 |
| 93 | 85.8 | 12,217 | 96.7 | 13,769 | 100.6 | 14,623 | 87.9 | 12,449 | 99.5 | 14,092 | 103.0 | 14,787 |
| 94 | 86.8 | 12,217 | 97.8 | 13,765 | 102.0 | 14,619 | 88.9 | 12,441 | 100.5 | 14,064 | 103.5 | 14,628 |
| 95 | 88.1 | 12,258 | 99.3 | 13,817 | 103.2 | 14,568 | 90.2 | 12,474 | 101.5 | 14,037 | 103.5 | 14,300 |
| 96 | 89.1 | 12,255 | 100.3 | 13,796 | 103.5 | 14,469 | 91.2 | 12,474 | 102.8 | 14,061 | 103.5 | 14,024 |
| 97 | 90.1 | 12,251 | 101.6 | 13,815 | 103.5 | 14,229 | 92.5 | 12,515 | 103.8 | 14,044 | 103.5 | 13,782 |
| 98 | 91.1 | 12,248 | 103.3 | 13,888 | 103.5 | 13,977 | 93.2 | 12,475 | 105.5 | 14,121 | 103.5 | 13,576 |
| 99 | 92.7 | 12,323 | 104.2 | 13,852 | 103.5 | 13,744 | 94.2 | 12,475 | 106.8 | 14,143 | 103.5 | 13,404 |
| 100 | 94.1 | 12,371 | 105.2 | 13,830 | 103.5 | 13,543 | 94.9 | 12,435 | 108.5 | 14,217 | 103.5 | 13,254 |
| 101 | 94.7 | 12,316 | 106.9 | 13,902 | 103.5 | 13,365 | 95.5 | 12,380 | 109.8 | 14,234 | 103.5 | 13,114 |
| 102 | 95.7 | 12,313 | 107.9 | 13,883 | 103.5 | 13,205 | 97.2 | 12,467 | 111.2 | 14,263 | 103.5 | 12,979 |
| 103 | 97.0 | 12,348 | 109.5 | 13,940 | 103.5 | 13,061 | 98.2 | 12,464 | 113.2 | 14,368 | 103.5 | 12,852 |
|  | **IHR Unit 3 c** |
|  | *Out of service until 2021 for installation of a new adjustable-blade runner design.* |

|  |  |  |
| --- | --- | --- |
| **Project** | **IHR Unit 4 (Locked Blades) – with STS** | **IHR Unit 4 (Locked Blades) – no STS** |
| **Head** | **Lower Limit** | **Peak Efficiency** | **Upper Limit** | **Lower Limit** | **Peak Efficiency** | **Upper Limit** |
| **(feet)** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** |
| 85 | 76.6 | 12,206 | 79.6 | 12,608 | 83.5 | 13,302 | 77.7 | 12,161 | 81.3 | 12,650 | 84.7 | 13,251 |
| 86 | 78.0 | 12,265 | 80.8 | 12,632 | 84.4 | 13,277 | 79.1 | 12,221 | 82.5 | 12,668 | 85.6 | 13,227 |
| 87 | 79.3 | 12,323 | 81.9 | 12,656 | 85.3 | 13,252 | 80.5 | 12,279 | 83.6 | 12,685 | 86.6 | 13,203 |
| 88 | 80.7 | 12,379 | 83.1 | 12,678 | 86.2 | 13,228 | 81.9 | 12,335 | 84.8 | 12,702 | 87.5 | 13,178 |
| 89 | 82.1 | 12,433 | 84.3 | 12,700 | 87.1 | 13,204 | 83.3 | 12,389 | 86.0 | 12,718 | 88.4 | 13,155 |
| 90 | 83.4 | 12,486 | 85.5 | 12,721 | 88.1 | 13,180 | 84.7 | 12,442 | 87.1 | 12,733 | 89.4 | 13,131 |
| 91 | 84.4 | 12,491 | 86.5 | 12,729 | 89.2 | 13,194 | 85.7 | 12,447 | 88.2 | 12,742 | 90.5 | 13,145 |
| 92 | 85.5 | 12,496 | 87.6 | 12,738 | 90.3 | 13,208 | 86.7 | 12,452 | 89.3 | 12,751 | 91.6 | 13,159 |
| 93 | 86.5 | 12,500 | 88.7 | 12,746 | 91.5 | 13,221 | 87.8 | 12,456 | 90.4 | 12,760 | 92.8 | 13,172 |
| 94 | 87.5 | 12,504 | 89.7 | 12,753 | 92.6 | 13,234 | 88.8 | 12,460 | 91.5 | 12,768 | 93.9 | 13,185 |
| 95 | 88.5 | 12,508 | 90.8 | 12,760 | 93.7 | 13,246 | 89.8 | 12,464 | 92.6 | 12,776 | 95.1 | 13,197 |
| 96 | 89.5 | 12,511 | 91.8 | 12,767 | 94.9 | 13,262 | 90.8 | 12,468 | 93.6 | 12,783 | 96.3 | 13,214 |
| 97 | 90.5 | 12,514 | 92.9 | 12,773 | 96.0 | 13,277 | 91.9 | 12,471 | 94.7 | 12,790 | 97.5 | 13,229 |
| 98 | 91.5 | 12,517 | 94.0 | 12,779 | 97.2 | 13,293 | 92.9 | 12,473 | 95.8 | 12,797 | 98.6 | 13,245 |
| 99 | 92.5 | 12,519 | 95.0 | 12,785 | 98.4 | 13,307 | 93.9 | 12,476 | 96.9 | 12,803 | 99.8 | 13,259 |
| 100 | 93.6 | 12,521 | 96.1 | 12,790 | 99.5 | 13,321 | 95.0 | 12,478 | 98.0 | 12,809 | 101.0 | 13,273 |
| 101 | 94.6 | 12,530 | 97.1 | 12,794 | 100.8 | 13,348 | 96.0 | 12,487 | 99.0 | 12,812 | 102.2 | 13,300 |
| 102 | 95.6 | 12,538 | 98.1 | 12,797 | 102.0 | 13,374 | 97.0 | 12,496 | 100.0 | 12,814 | 103.5 | 13,326 |
| 103 | 96.6 | 12,547 | 99.1 | 12,800 | 103.2 | 13,399 | 98.1 | 12,504 | 101.1 | 12,817 | 104.7 | 13,352 |
| 104 | 97.7 | 12,555 | 100.1 | 12,803 | 104.4 | 13,424 | 99.1 | 12,512 | 102.1 | 12,819 | 106.0 | 13,376 |
| 105 | 98.7 | 12,562 | 101.2 | 12,806 | 105.6 | 13,449 | 100.1 | 12,520 | 103.1 | 12,821 | 107.2 | 13,401 |
| **Project**  | **IHR Units 5, 6 (Locked Blades) – with STS** | **IHR Units 5, 6 (Locked Blades) – No STS** |
| **Head** | **Lower Limit** | **Peak Efficiency** | **Upper Limit** | **Lower Limit** | **Peak Efficiency** | **Upper Limit** |
| **(feet)** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** |
| 85 | 82.4 | 13,129 | 85.5 | 13,458 | 87.5 | 13,933 | 79.8 | 12,475 | 83.3 | 12,884 | 91.0 | 14,224 |
| 86 | 83.8 | 13,184 | 86.6 | 13,470 | 88.5 | 13,916 | 81.1 | 12,527 | 84.6 | 12,914 | 92.0 | 14,208 |
| 87 | 85.2 | 13,237 | 87.8 | 13,482 | 89.5 | 13,900 | 82.5 | 12,578 | 85.8 | 12,943 | 93.1 | 14,191 |
| 88 | 86.6 | 13,288 | 88.9 | 13,492 | 90.5 | 13,884 | 83.8 | 12,627 | 87.1 | 12,971 | 94.1 | 14,175 |
| 89 | 88.0 | 13,339 | 90.1 | 13,503 | 91.5 | 13,867 | 85.2 | 12,675 | 88.3 | 12,998 | 95.1 | 14,159 |
| 90 | 89.4 | 13,387 | 91.2 | 13,513 | 92.5 | 13,851 | 86.5 | 12,721 | 89.6 | 13,024 | 96.2 | 14,143 |
| 91 | 90.4 | 13,390 | 92.4 | 13,524 | 93.7 | 13,867 | 87.5 | 12,724 | 90.6 | 13,032 | 97.4 | 14,159 |
| 92 | 91.5 | 13,392 | 93.5 | 13,534 | 94.9 | 13,883 | 88.6 | 12,726 | 91.7 | 13,040 | 98.6 | 14,174 |
| 93 | 92.5 | 13,394 | 94.6 | 13,545 | 96.0 | 13,897 | 89.6 | 12,728 | 92.8 | 13,047 | 99.9 | 14,190 |
| 94 | 93.6 | 13,396 | 95.8 | 13,555 | 97.2 | 13,912 | 90.6 | 12,730 | 93.9 | 13,054 | 101.1 | 14,204 |
| 95 | 94.6 | 13,397 | 96.9 | 13,564 | 98.4 | 13,926 | 91.6 | 12,732 | 95.0 | 13,061 | 102.3 | 14,219 |
| 96 | 95.5 | 13,362 | 98.0 | 13,569 | 99.6 | 13,943 | 92.4 | 12,698 | 96.0 | 13,054 | 103.6 | 14,237 |
| 97 | 96.3 | 13,327 | 99.1 | 13,574 | 100.8 | 13,960 | 93.2 | 12,665 | 97.0 | 13,047 | 104.8 | 14,254 |
| 98 | 97.1 | 13,292 | 100.3 | 13,578 | 102.1 | 13,976 | 93.9 | 12,632 | 98.0 | 13,039 | 106.1 | 14,271 |
| 99 | 97.9 | 13,258 | 101.4 | 13,582 | 103.3 | 13,991 | 94.7 | 12,600 | 99.0 | 13,032 | 107.4 | 14,287 |
| 100 | 98.7 | 13,225 | 102.5 | 13,586 | 104.5 | 14,007 | 95.5 | 12,568 | 100.0 | 13,025 | 108.7 | 14,302 |
| 101 | 99.8 | 13,240 | 103.6 | 13,588 | 105.7 | 14,026 | 96.6 | 12,583 | 101.1 | 13,023 | 109.9 | 14,322 |
| 102 | 100.9 | 13,255 | 104.6 | 13,590 | 106.9 | 14,044 | 97.7 | 12,597 | 102.1 | 13,021 | 111.2 | 14,341 |
| 103 | 102.0 | 13,269 | 105.7 | 13,592 | 108.1 | 14,063 | 98.8 | 12,611 | 103.1 | 13,019 | 112.5 | 14,360 |
| 104 | 103.2 | 13,283 | 106.8 | 13,594 | 109.4 | 14,081 | 99.8 | 12,624 | 104.1 | 13,018 | 113.7 | 14,378 |
| 105 | 104.3 | 13,297 | 107.8 | 13,596 | 110.6 | 14,098 | 100.9 | 12,637 | 105.1 | 13,016 | 115.0 | 14,396 |

1. Values provided by HDC (Mar 2007), as updated for Unit 2 with new runner design (Apr 2019) and Units 4, 5, 6 with locked blades (Dec 2019 and Jun 2021). Flow (cfs) was calculated based on turbine efficiency, project head, and power output (MW).
2. “Operating Limit” is the maximum safe operating point based on cavitation or generator limit (added Feb 2018). IHR Units 1-3 have a generator limit that restricts turbine output at higher heads. Values shaded in gray indicate the Operating Limit is below the 1% Upper Limit.
3. Unit 2 was rebuilt with a new fixed-blade runner design to reduce impacts to fish (completed May 2019). Unit 3 is out of service in 2021 for installation of a new adjustable-blade runner design.
4. Units 4, 5, and 6 have locked runner blades and a restricted operating range until the blade seals are repaired or replaced. Operating range values are based on abbreviated index tests for Unit 4 (2021), Unit 5 (2017), and Unit 6 (2019).