# Fish Passage Plan (FPP) Change Form

**Change Form # & Title**: 21IHR007 – Unit 2 Operating Range

**Date Submitted**: October 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 final operating ranges for Ice Harbor Unit 2 based on index tests with and without screens in February 2021 and April 2021 and Voith model test data. These values replace the preliminary ranges added in 2020 that were based only on model test data.

**Proposed Change**:

See next page.

**Comments**:

**Record of Final Action**:

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 | 77.2 | 12,179 | 87.1 | 13,753 | 89.4 | 14,254 | 77.9 | 12,193 | 88.1 | 13,795 | 91.2 | 14,392 |
| 86 | 78.5 | 12,225 | 88.3 | 13,750 | 90.8 | 14,290 | 79.1 | 12,232 | 89.4 | 13,810 | 92.7 | 14,389 |
| 87 | 79.8 | 12,265 | 89.5 | 13,759 | 92.2 | 14,333 | 80.4 | 12,272 | 90.7 | 13,835 | 94.2 | 14,509 |
| 88 | 81.1 | 12,303 | 90.8 | 13,769 | 93.6 | 14,363 | 81.7 | 12,310 | 92.1 | 13,877 | 95.6 | 14,511 |
| 89 | 82.4 | 12,339 | 92.0 | 13,776 | 95.0 | 14,474 | 82.9 | 12,336 | 93.6 | 13,924 | 97.1 | 14,500 |
| 90 | 83.7 | 12,373 | 93.2 | 13,777 | 96.4 | 14,508 | 84.1 | 12,351 | 95.1 | 13,963 | 98.6 | 14,619 |
| 91 | 85.0 | 12,399 | 94.5 | 13,778 | 97.8 | 14,526 | 85.1 | 12,349 | 96.6 | 14,006 | 100.1 | 14,643 |
| 92 | 86.1 | 12,401 | 95.8 | 13,800 | 99.2 | 14,536 | 86.3 | 12,364 | 98.0 | 14,049 | 101.5 | 14,762 |
| 93 | 86.8 | 12,354 | 96.9 | 13,803 | 100.6 | 14,623 | 87.3 | 12,366 | 98.9 | 14,007 | 103.0 | 14,787 |
| 94 | 87.5 | 12,325 | 98.3 | 13,845 | 102.0 | 14,619 | 87.9 | 12,307 | 100.3 | 14,050 | 103.5 | 14,628 |
| 95 | 88.8 | 12,381 | 99.3 | 13,835 | 103.2 | 14,568 | 89.4 | 12,368 | 101.6 | 14,062 | 103.5 | 14,300 |
| 96 | 89.8 | 12,389 | 100.8 | 13,907 | 103.5 | 14,469 | 90.6 | 12,393 | 103.0 | 14,083 | 103.5 | 14,024 |
| 97 | 90.8 | 12,389 | 102.0 | 13,917 | 103.5 | 14,229 | 92.1 | 12,455 | 104.3 | 14,110 | 103.5 | 13,782 |
| 98 | 91.9 | 12,384 | 103.6 | 13,970 | 103.5 | 13,977 | 93.4 | 12,491 | 105.8 | 14,146 | 103.5 | 13,576 |
| 99 | 92.9 | 12,374 | 105.1 | 14,006 | 103.5 | 13,744 | 94.2 | 12,466 | 107.2 | 14,182 | 103.5 | 13,404 |
| 100 | 93.8 | 12,364 | 106.4 | 14,033 | 103.5 | 13,543 | 95.4 | 12,501 | 108.6 | 14,225 | 103.5 | 13,254 |
| 101 | 94.7 | 12,358 | 107.8 | 14,068 | 103.5 | 13,365 | 96.7 | 12,541 | 110.0 | 14,266 | 103.5 | 13,114 |
| 102 | 95.8 | 12,364 | 109.2 | 14,088 | 103.5 | 13,205 | 97.5 | 12,520 | 111.4 | 14,310 | 103.5 | 12,979 |
| 103 | 96.9 | 12,370 | 110.5 | 14,107 | 103.5 | 13,061 | 98.3 | 12,503 | 112.9 | 14,357 | 103.5 | 12,852 |
|  | **IHR Unit 3 c** |
|  | *Out of service until 2022 for installation of a new Kaplan (adjustable) runner design.* |

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| **Project**  | **IHR Unit 4 (Blades Hydro Locked at 22.3°) – with STS d** | **IHR Unit 4 (Blades Hydro Locked at 22.3°) – No STS d** |
| **Head** | **1% Lower Limit** | **Peak Efficiency** | **1% Upper Limit** | **1% Lower Limit** | **Peak Efficiency** | **1% 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 |
|  | **IHR Units 5, 6 (Blades Locked at 23.8°) – with STS d** | **IHR Units 5, 6 (Blades Locked at 23.8°) – No STS d** |
| 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 (Sep 2021) and Units 4, 5, 6 with locked blades (Dec 2019, 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 generator limit restricts turbine output at higher heads. Values in gray indicate Operating Limit is below 1% Upper Limit.
3. Unit 2 was rebuilt with a new Voith non-adjustable runner design to reduce impacts to fish (completed May 2019). Unit 3 is out of service until 2022 for installation of a new Voith Kaplan (adjustable) 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. Table values are based on abbreviated index tests for U4 (hydraulic) in 2021, U5 (welded) in 2017, and U6 (hydraulic) in 2019.